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A Division of the American Association of Petroleum Geologists

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JOURNAL OF PALEONTOLOGY

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VOLUME 15 JANUARY, 1941 NUMBER 1

CENOZOIC REGULAR ECHINOIDS OF EASTERN UNITED STATES

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ABSTRACT—This paper lists or describes 8 early Eocene, 1 medial Eocene, 9 late Eocene, 5 late Oligocene, 2 early Miocene, 3 late Miocene, 3 Pliocene, and 8 Recent or Pleistocene species, 39 species in all, of regular echinoids from the Atlantic and Gulf Coastal Plain of the United States. Eleven species are described as new. A key to the 19 genera represented is based chiefly on characters of the ambulacral areas.

THIS PAPER treats of all the known regular echinoids from the Cenozoic deposits of the Atlantic and Gulf Coastal Plain of the United States and the more common species living in the adjacent waters. As many of the species are described and figured in Clark and Twitchell's monograph on the Mesozoic and Cenozoic Echinodermata of the United States (U. S. Geol. Survey Mon. 54), which can still be purchased from the Superintendent of Documents, Government Printing Office, at Washington, it has not been deemed necessary to refigure or redescribe all of them, though the nomenclature has been thoroughly revised and the stratigraphic position and occurrence has been brought up to date. The work is based primarily on collections in the United States National Museum. Following is a list of the species included showing their stratigraphic range.

STRATIGRAPHIC RANGE OF CENOZOIC REGULAR ECHINOIDS

		Page
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Cidaris tribuloides (Lamarck).	Recent to Miocene?	5
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The regular echinoids are those in which the periproct (the region surrounding the anal opening, which is rarely preserved in fossils) lies on the upper surface within the apical system (the ring of genital and ocular plates, which are more frequently preserved) and opposite the mouth, which is central on the lower surface within a membranous area called the peristome. Only the genera treated in this paper are included in the following key, which should therefore be used with caution. Many other genera may fit the key, though they differ from genera in it by characters not used in its construction.

Key to the Genera of East-American Cenozoic Regular Echinoids

1. Ambulacral areas ribbon-shaped, narrow, without primary tubercles.
   2. Ambulacral plates having only one pair of pores; periproct central.....Cidaridae.
      3. Paired pores evidently farther apart than the diameter of the pores, horizontal...*Phyllacanthus.*
      3. Paired pores not farther apart than the diameter of the pores, oblique.
         4. Tubercles perforate.
            5. Apical system nearly circular, without reentrant angles.....*Cidaris.*
            5. Apical system not circular, with reentrant angles.....*Dorocidaris.*
         4. Tubercles imperforate.....*Tylocidaris.*
   2. Ambulacral plates having two pairs of pores; periproct eccentric; tubercules imperforate.....Saleniidae, *Salenia.*
1. Ambulacral areas petal-shaped, wider, with primary tubercles.
   2. Tubercles perforate.....Centrechinidae, *Pseudodiadema.*
   2. Tubercles imperforate.
      3. Ambulacral areas pitted near peristome; interambulacral areas above the ambitus generally partly bare.....Arbaciidae.
         4. Ambulacral areas surrounded by a nodular thread.....*Coelopleurus.*
         4. Ambulacral areas not surrounded by a nodular thread.....*Arbacia.*
      3. Ambulacral areas not pitted near peristome; interambulacral areas above the ambitus generally not bare.
         4. Ambulacral pores not arranged in disconnected arcs of more than three pairs.Echinidae.
            5. Pore pairs in single, straight, continuous rows, not conspicuously crowded around the peristome.
               6. Tubercles crenulated; not conspicuously granulated or rugose.
                  7. Test strongly oblate.....*Microsoma.*
                  7. Test not strongly oblate.....*Thylechinus.*
               6. Tubercles not crenulated; granulated or rugose.
                  7. Granules separated, not rugose.....*Stirechinus.*
                  7. Granules confluent, rugose.....*Progonechinus.*
            5. Pore pairs not in single, straight, continuous rows throughout; pairs crowded around the peristome.

6. Pore pairs in disconnected groups of three.
   7. Pairs of each group in a diagonal straight line.....*Psammechinus.*
   7. Pairs of each group not in a diagonal straight line.....*Lytechinus.*
6. Pore pairs not in disconnected groups of three.
   7. Pairs above the ambitus in parallel rows, not arcs.
      8. Pairs above the ambitus in two rows; pairs below the ambitus in connected arcs.....*Phymosoma.*
      8. Pairs in three rows throughout, the middle row crooked, disconnected.*Tripneustes.*
   7. Pairs above the ambitus in connected arcs, not parallel rows.....*Phymotaxis.*
4. Ambulacral pores arranged in disconnected arcs of more than three pairs, the arcs straightening into parallel inclined rows below the ambitus.
   5. Test generally elongated; primary tubercles large.....Echinometridae, *Echinometra.*
   5. Test not elongated; primary tubercles small.....Strongylocentrotidae, *Strongylocentrotus.*

SYSTEMATIC DESCRIPTIONS

Family CIDARIDAE

KEY TO THE SPECIES OF EAST-AMERICAN CENOZOIC CIDARIDAE

1. Paired pores evidently farther apart than the diameter of the pores, horizontal; late Eocene.....*Phyllacanthus mortoni* (Conrad)
1. Paired pores not farther apart than the diameter of the pores, oblique;
   2. Tubercles perforate.
      3. Apical system nearly circular, without reentrant angles.....*Cidaris.*
         4. Tubercles not crowded vertically, not crenulated; early Eocene.....*Cidaris splendens.*
         4. Tubercles crowded vertically.
            5. Some tubercles incipiently crenulated; late Eocene.....*Cidaris smithi.*
            5. Tubercles not crenulated; Recent.....*Cidaris tribuloides.*
      3. Apical system not circular, with reentrant angles.....*Dorocidaris.*
         4. Primary spines more or less smooth; Recent.....*Dorocidaris abyssicola.*
         4. Primary spines generally not smooth; Recent.....*Dorocidaris rugosa.*
   2. Tubercles imperforate; early Eocene.....*Tylocidaris walcotti* (Clark).

Genus PHYLLACANTHUS Brandt, 1835

Phyllacanthus BRANDT, *1835*, Acad. imp. Sci. St. Pétersbourg, Recueil des Actes, p. 267.
Phyllacanthus AGASSIZ, *1872*, Harvard College, Mus. Comp. Zool., Mem., vol. 3, pt. 2, p. 387.
Phyllacanthus DÖDERLEIN, *1906*, Wissenschaftliche Ergebnisse der Deutschen Tiefsee-Expedition auf dem Dampfer "Valdivia" 1898–1899, Band 5, 2d Lief., p. 103.
Phyllacanthus H. L. CLARK, *1907*, Harvard College, Mus. Comp. Zool., Bull., vol. 51, no. 7, p. 186.
Rabdocidaris DESOR, *1858*, Synopsis des échinides fossiles, p. 39.
Rhabdocidaris COTTEAU, *1862*, Paléontologie française, sér. 1, t. 7, p. 335.

Genotype, *Cidarites imperialis* Lamarck, living in the East Indies, designated by Döderlein, 1906.

The most conspicuous difference between *Phyllacanthus* and *Cidaris* and other related genera is in the poriferous zones. The pores of each pair are farther apart, horizontal, and connected by a groove in *Phyllacanthus*, but close together, slanting, and separated by a bump or ridge in other Cidaridae.

PHYLLACANTHUS MORTONI (Conrad)
Plate 1, figures 16–18

?Cidaris alabamensis MORTON, *1846*, Acad. Nat. Sci. Philadelphia, Proc., vol. 3, p. 51.
Cidarites mortoni CONRAD, *1850*, idem, Jour., ser. 2, vol. 2, p. 40, pl. 1, fig. 13.
Cidaris carolinensis EMMONS, *1858*, Agriculture of the eastern counties, p. 305, fig. 238.
?Cidaris mitchellii EMMONS, *1858*, idem, p. 305, fig. 237.
?Cidaris blandus DE GREGORIO, *1890*, Mon. faune éocenique de l'Alabama, p. 253, pl. 44, fig. 5.
?Cidaris modestus DE GREGORIO, *1890*, idem, p. 253, pl. 43, fig. 26.
?Cidaris moerens DE GREGORIO, *1890*, idem, p. 252, pl. 43, figs. 22, 23.
?Cidaris ordinatus DE GREGORIO, *1890*, idem, p. 252, pl. 44, fig. 1.
?Cidaris perdubius DE GREGORIO, *1890*, idem, p. 253, pl. 44, fig. 2
Cidaris mortoni CLARK and TWITCHELL, *1915*, U. S. Geol. Survey, Mon. 54, p. 157, pl. 73, fig. 1.
?Cidaris alabamensis CLARK and TWITCHELL, *1915*, idem, p. 116.
Cidaris carolinesis CLARK and TWITCHELL, *1915*, idem, p. 113, pl. 55, figs. 2a–c.
?Cidaris mitchelli CLARK and TWITCHELL, *1915*, idem, p. 113, pl. 55, figs. 1a–c.
?Cidaris blandis CLARK and TWITCHELL, *1915*, idem, p. 116.
?Cidaris modestus CLARK and TWITCHELL, *1915*, idem, p. 115.
?Cidaris moereus CLARK and TWITCHELL, *1915*, idem, p. 115.
?Cidaris ordinatus CLARK and TWITCHELL, *1915*, idem, p. 115.
?Cidaris perdubius CLARK and TWITCHELL, *1915*, idem, p. 116.

Cidaris georgiana CLARK, *1915*, idem, p. 158, pl. 73, fig. 4.
Leiocidaris carolinensis LAMBERT and THIÉRY, *1925*, Essai de nomenclature raisonée des échinides, fasc. 8, p. 560.
?Leiocidaris mitchelli LAMBERT and THIÉRY, *1925*, idem, p. 560.
Cidaris (*Dorocidaris*) *georgiana* LAMBERT and THIÉRY, idem, p. 560.

Occurrence.—ALABAMA: Washington County (type of *alabamensis*); five miles southeast of Whatley, Clarke County (station 7159, C. W. Cooke, collector); Claiborne (types of *blandus*, *modestus*, *moerens*, *ordinatus*, and *perdubius*).

GEORGIA: Near Palmyra, Lee County (type of *mortoni*); two miles north of Albany (station 3617, T. W. Vaughan, collector, type of *georgiana;* station 7121, C. W. Cooke and J. E. Brantly, collectors); Flint River at bridge of Seaboard Air Line Railway west of Coney (station 4034, S. W. McCallie, collector); Flint River at Normans Ferry, Mitchell County (station 7127, C. W. Cooke and J. E. Brantly, collectors); Bainbridge (station 6171, L. W. Stephenson, collector; station 7097, C. W. Cooke and W. C. Mansfield, collectors; U. S. Nat. Mus. 498881, figured specimen, A. F. Foerste, collector).

FLORIDA: Pit near Steinhatchee River, Taylor County (R. B. Becker, collector); Steinhatchee River opposite Clara (station 14541, C. W. Cooke and W. D. Havens, collectors); Kendrick (station 14125, W. C. Mansfield and C. W. Mumm, collectors).

NORTH CAROLINA: Craven County (types of *carolinensis* and *mitchellii*).

Geologic horizon.—Eocene: Jackson group; Moodys marl (Claiborne, Ala.), Ocala limestone (Clarke County, Ala., Florida, and Georgia), Castle Hayne marl (North Carolina).

Types.—The types of *alabamensis* and *mortoni* presumably are in the Academy of Natural Sciences of Philadelphia; those of *carolinensis* and *mitchellii* are in the United States National Museum, nos. 498881 and 498883, respectively; those of *blandus*, *modestus*, *moerens*, *ordinatus*, and *perdubius* are said to be in the De Gregorio collection at Palermo.

Remarks.—There seems little doubt that *Cidaris georgiana* Clark, a species very common in the Ocala limestone and the only one from Georgia in the United States National Museum, is identical with *Cidarites mortoni* Conrad, which is based on a fragment from the same formation and region described many years earlier. This species shows considerable variation in the size of the granules. The specimens with coarse granules are similar to *Cidaris carolinensis* Emmons, which is placed in the synonymy with considerable assurance. The granules of *mitchellii* Emmons are much finer but can be matched with selected specimens from Georgia. The holotypes of *carolinensis* and *mitchellii*, the only specimens from Craven County, N. C., available, probably represent merely individual variations of *C. mortoni*. The spines from Claiborne, Ala., described by De Gregorio under five different names probably represent this same species, though several of them are unrecognizable.

Cidaris alabamensis Morton has not been figured, nor can it be recognized from its description. If it should prove to be identical with this common upper Eocene species, its name will have priority.

This species, whose known geographic range extends from North Carolina to Alabama though its geologic range is limited to the late Eocene (Jackson), is referred to *Phyllacanthus* because the pores in each pair

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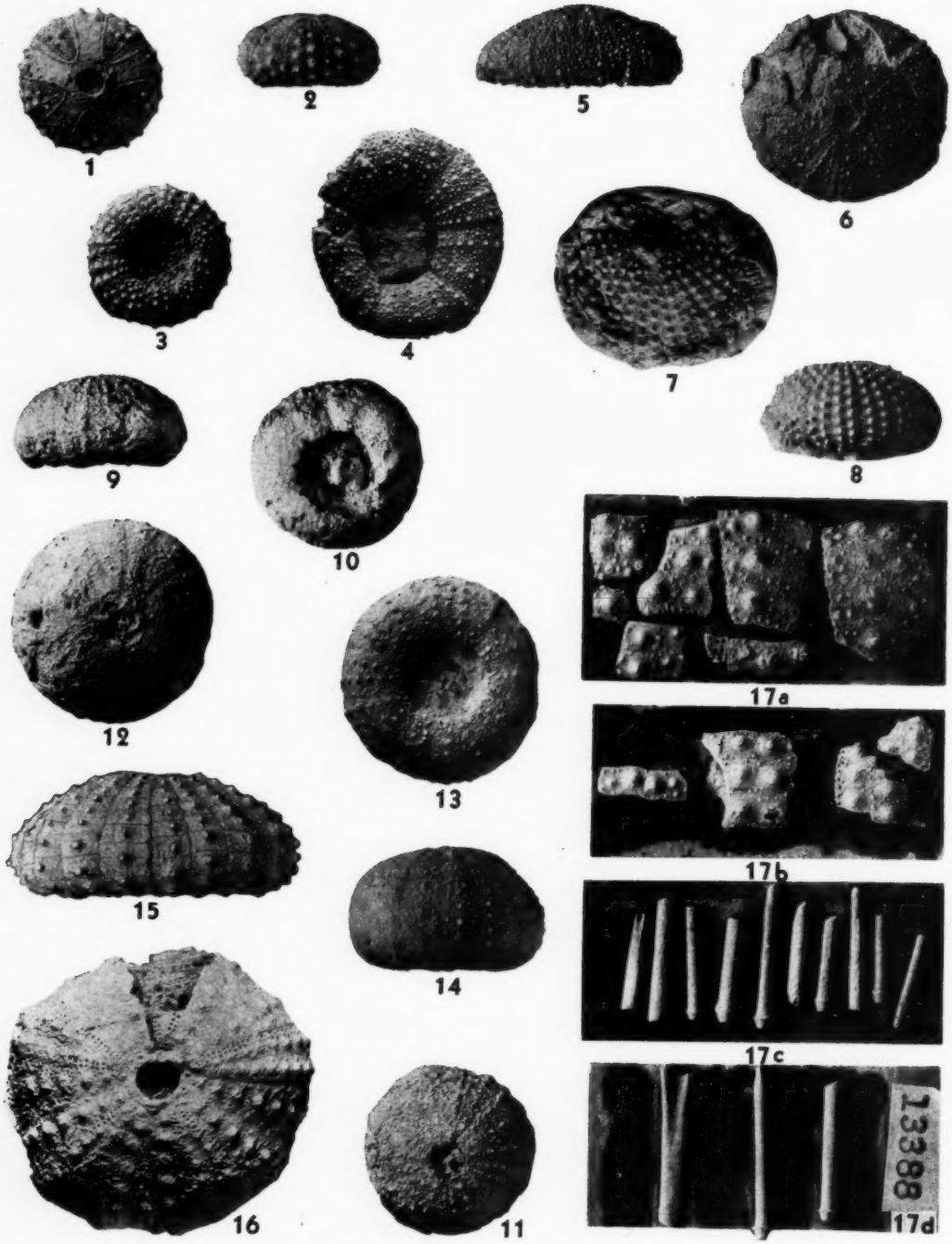
EXPLANATION OF PLATE 1

FIGS. *1–3—Arbacia waccamaw* Cooke, n. sp., holotype, 4½ miles southwest of Little River, S. C., U. S. Nat. Mus. 498888, side, upper, and lower views, ×1. (p. 10)
4–6—Arbacia rivuli Cooke, n. sp., holotype, 4½ miles southwest of Little River, S. C., U. S. Nat. Mus. 498887, top, bottom, and side views, ×1. (p. 10)
7–9—Arbacia improcera (Conrad), Suffolk, Va., U. S. Nat. Mus. 166487, top, side, and bottom views, ×1. (p. 11)
10, 11—Cidaris smithi Clark, holotype, The Rocks, Clarke County, Ala., U. S. Nat. Mus. 498880, side and top views, ×1. (p. 5)
12–15—Cidaris splendens (Morton), Salt Mountain, Ala., U. S. Nat. Mus. 498879, fragment and three spines, ×2. (p. 5)
16–18—Phyllacanthus mortoni (Conrad), Bainbridge, Ga., U. S. Nat. Mus. 498881, bottom, side, and top views, ×1. (p. 3)

Cooke, Cenozoic Echinoids



Cooke, Cenozoic Echinoids

are distant and connected by a horizontal groove.

Genus CIDARIS Leske, 1778

Cidaris papillata (part) LESKE, *1778*, Additamenta ad Kleinii Echinodermata, p. 125.
Cidaris, A. AGASSIZ, *1872*, Harvard College, Mus. Comp. Zool., Mem., vol. 3, p. 252.
Cidaris H. L. CLARK, 1907, idem, Bull., vol. 51, no. 7, p. 183.

Genotype, *Cidarites tribuloides* Lamarck, living in the Atlantic Ocean, designated by H. L. Clark (1907, p. 174). Clark thinks that *C. tribuloides* represents a part of the composite group called *C. papillata* by Leske. Agassiz restricted *papillata* to another part of this group and transferred it to *Dorocidaris*. Clark credits the designation to Brandt (1835, p. 68), though the route by which Clark arrives at that conclusion appears rather devious.

CIDARIS TRIBULOIDES (Lamarck)

Cidaris papillata (part) LESKE, *1778*, Additamenta ad Kleinii Echinodermata, p. 125.
Cidarites tribuloides LAMARCK, *1816*, Histoire naturelle des animaux sans vertèbres, vol. 3, p. 56; 2d ed., 1840, vol. 3, p. 380.
Cidaris tribuloides A. AGASSIZ, *1872*, Harvard College, Mus. Comp. Zoology, Mem., vol. 3, pt. 2, pp. 99, 253, pl. 1d; pl. 2, figs. 1–3; pl. 2c, fig. 13.
Cidaris tribuloides H. L. CLARK; *1907*, idem, Bull., vol. 51, no. 7, p. 185.
Cidaris tribuloides JACKSON, *1922*, Carnegie Inst. Washington, Pub. 306, p. 23, pl. 1, figs. 18–20.

Occurrence.—Atlantic Ocean from the Bermudas and Azores on the north to Brazil, the Cape Verde Islands, and Cape Palmas on the south (Clark).

Geologic horizon.—Recent to Miocene (?).

Type.—Jardin des Plantes, Paris (*fide* A. Agassiz).

Remarks.—This common West Indian species has not yet been reported fossil from the United States, though it may occur in the Pleistocene deposits of the Southeastern States. Jackson figures it from questionable Miocene deposits near Santiago de Cuba. It is distinguishable from *Dorocidaris abyssicola* by the greater crowding of its primary tubercles, which are conspicuously raised, not sunken as in *Dorocidaris*.

CIDARIS SPLENDENS (Morton)

Plate 1, figures 12–15

Cidarites splendeus MORTON, *1841*, Acad. Nat. Sci. Philadelphia, Proc., vol. 1, p. 132.
Cidaris splendens CLARK, *1915*, U. S. Geol. Survey, Mon. 54, p. 46, pl. 9, figs. 4a–b, 5a–f, 6.

Occurrence.—Timber Creek, N. J. (type); Vincentown, N. J. (U. S. National Museum 29469, F. B. Meek, collector); Salt Mountain, 6 miles south of Jackson, Ala. (station 13395, C. W. Cooke, collector; station 3646, T. W. Vaughan, collector); Richmond Branch, ½ mile north of Salt Mountain, Ala. (L. D. Toulmin, collector).

Geologic horizon.—Eocene, Vincentown sand (New Jersey); Salt Mountain limestone (Alabama).

Type.—Acad. Nat. Sci. Philadelphia.

Remarks.—The figured fragment from Alabama, U. S. Nat. Mus. 498879, is remarkably similar to the specimens from New Jersey figured by Clark.

CIDARIS SMITHI Clark

Plate 1, figures 10, 11

Cidaris smithi CLARK, *1915*, U. S. Geol. Survey, Mon. 54, p. 157, pl. 73, figs. 2a–c, 3.

EXPLANATION OF PLATE 2

FIGS. *1–3*—*Coelopleurus carolinensis* Cooke, n. sp., holotype, Wilmington, N. C., U. S. Nat. Mus. 166500, upper, side, and lower views, ×1½. (p. 9)
4–6—*Progonechinus pretiosus* (Clark), holotype, Dead Level, Choctaw County, Ala., U. S. Nat. Mus. 146455, lower, side, and upper views, ×1½. (p. 15)
7, 8—*Psammechinus santee* Cooke, n. sp., syntypes, Orangeburg County, S. C., U. S. Nat. Mus. 498890, guttapercha squeezes, ×1½. (p. 15)
9–11—*Psammechinus? ocalanus* Cooke, n. sp., holotype, Bainbridge, Ga., U. S. Nat. Mus. 498889, side, lower, and upper views, ×1½. (p. 16)
12–14—*Thylechinus* (*Gagaria*) *salis* Cooke, n. sp., holotype, Salt Mountain, Ala., U. S. Nat. Mus. 166497, upper, lower, and side views, ×1½. (p. 13)
15—*Phymosoma dixie* Cooke, n. sp., holotype, Clara, Fla., U. S. Nat. Mus. 372867, side view, ×1. (p. 17)
16—*Thylechinus* (*Gagaria*) *mossomi* Cooke, n. sp., Blackwater Creek, Fla., U. S. Nat. Mus. 498884, upper view, ×1½. (p. 13)
17a–d—*Thylechinus* (*Gagaria*) *chickasawhay* Cooke, n. sp., syntypes, near Waynesboro, Miss., fragments of test and detached spines, U. S. Nat. Mus. 498885, ×1½. (p. 14)

Cidaris pratti CLARK, *1915*, idem, p. 114, pl. 55, fig. 3.
Cidaris (*Dorocidaris*) *smithi* LAMBERT and THIÉRY, 1925, Essai de nomenclature raisonnée des échinides, fasc. 8, p. 560.
Cidaris pratti LAMBERT and THIÉRY, *1925*, idem, p. 559.
Cidaris pratti KELLUM, *1926*, U. S. Geol. Survey, Prof. Paper 143, p. 14.

Occurrence.—The Rocks, sec. 35, T. 9 N., R. 1 E., Clarke County, Ala. (holotype, T. H. Aldrich, collector). Wilmington, N. C. (stations 782, type of *C. pratti*, and 783, T. W. Stanton, collector; station 5611; U. S. Nat. Mus. 166500b and 166504, L. W. Stephenson, collector; station 7302, B. L. Miller, collector); Castle Hayne, N. C. (station 4286, L. W. Stephenson, collector).

Geologic horizon.—Eocene, Ocala limestone (Alabama) and Castle Hayne marl (North Carolina).

Type.—Holotype, U. S. Nat. Mus. 498-880, deposited by Alabama Geol. Survey. Holotype of *C. pratti*, U. S. Nat. Mus. 164663.

Remarks.—The specimens from North Carolina, including the holotype of *pratti*, appear to have slightly narrower poriferous zones, and their primary tubercles occupy proportionately more of the plates than in the holotype of *smithi*. These differences are probably a function of the size, for the holotype of *smithi* is larger than the other specimens. The name *smithi* is preferred to *pratti*, which has page and plate precedence, because its holotype is more nearly complete. Some of the tubercles of this species are smooth; others are weakly crenulated.

Genus DOROCIDARIS A. Agassiz, 1869

Dorocidaris A. AGASSIZ, *1869*, Harvard College, Mus. Comp. Zool., Bull., vol. 1, p. 253.
Cidaris (*Dorocidaris*) A. AGASSIZ, *1872*, idem, Mem., vol. 3, p. 105; 1873, idem, p. 386.
Dorocidaris H. L. CLARK, *1907*, idem, Bull., vol. 51, no. 7, p. 207.

Genotype, *Dorocidaris abyssicola* A. Agassiz, 1869, living in the Western Atlantic; by monotypy.

DOROCIDARIS ABYSSICOLA A. Agassiz

Dorocidaris abyssicola A. AGASSIZ, *1869*, Harvard College, Mus. Comp. Zool., Bull., vol. 1, p. 253.
Dorocidaris papillata (part) Leske. A. AGASSIZ, *1872*, idem, Mem., vol. 3, p. 254, pl. 1, figs. 1–4.
Dorocidaris abyssicola H. L. CLARK, *1907*, idem, Bull., vol. 51, no. 7, p. 208.

Occurrence.—St. Lucia northward to the coast of South Carolina and the region south of Martha's Vineyard (Clark).

Type.—Probably Mus. Comp. Zool., Cambridge, Mass.

Remarks.—Agassiz (1872) united this species with the very variable *D. papillata*, but Clark points out constant differences between them. It has not been reported fossil.

DOROCIDARIS RUGOSA H. L. Clark

Dorocidaris rugosa H. L. CLARK, *1907*, Harvard College, Mus. Comp. Zool., Bull., vol. 51, no., 7, p. 210, pls. 4, 5; pl. 7, figs. 5–8.

Occurrence.—Latitude 32°N., off Savannah, Ga., to Barbados and St. Vincent.

Geologic horizon.—Recent.

Type.—The only specimens mentioned by Clark are eight in the United States National Museum.

Genus TYLOCIDARIS Pomel, 1883

Tylocidaris POMEL, *1883*, Classification méthodique et genera des échinides vivants et fossiles, p. 109.
Tylocidaris H. L. CLARK, *1909*, Harvard College, Mus. Comp. Zool., Bull., vol. 51, p. 183.
Tylocidaris LAMBERT and THIÉRY, *1910*, Essai de nomenclature raisonnée des échinides, p. 156.

Genotype, *Cidaris gibberula* Agassiz and Desor, Cenomanian of France, designated by Clark (1909, p. 177). This species is figured by Cotteau (1862, p. 234. pl. 1051, figs. 15–18; pl. 1054, figs. 1–7).

The imperforate tubercles distinguish *Tylocidaris* from *Cidaris* and other related genera.

TYLOCIDARIS WALCOTTI (Clark)

Cidaris walcotti CLARK, *1891*, Johns Hopkins Univ. Circ., vol. 10, no. 87, p. 75.
Cidaris walcotti CLARK, *1915*, U. S. Geol. Survey, Mon. 54, p. 45, pl. 9, figs. 3a–d.
Cidaris walcotti LAMBERT and THIÉRY, *1925*, Essai de nomenclature raisonnée des échinides, p. 559.

Occurrence.—Timber Creek, N. J. (type); Vincentown, N. J.

Geologic horizon.—Early Eocene, Vincentown sand.

Type.—Acad. Nat. Sci. Philadelphia, 1451.

Remarks.—There are no identified specimens of *Tylocidaris walcotti* in the United States National Museum. Clark's description and figures indicate that it differs from

other known American Cidaridae in that its tubercles are imperforate. It appears to be very similar to *T. gibberula*, the genotype, as figured by Cotteau.

Family SALENIIDAE

Genus SALENIA Gray, 1835

Salenia GRAY, *1835*, Zool. Soc. London, Proc., vol. 3, p. 58.
Salenia L. AGASSIZ, *1838*, Mon. d'échinodermes, Mon. 1, p. 6.
Salenia AGASSIZ and DESOR, *1847*, Catalogue raisonné . . . des échinodermes, p. 37.
Salenia DESOR, *1856*, Synopsis des échinides fossiles, fasc. 3, p. 148.
Salenia COTTEAU, *1861*, Paléontologie française, sér. 1, t. 7, p. 130.
Salenia DUNCAN and SLADEN, *1882*, Paleontologia Indica, ser. 14, vol. 1, pt. 3, fasc. 2, p. 28.
Salenia POMEL, *1883*, Classification méthodique et genera des échinides, vivants et fossiles, p. 93.
Salenia COTTEAU, *1892*, Paléontologie française, sér. 1, t. 2, p. 479.
Salenia AGASSIZ and CLARK, *1908*, Harvard College, Mus. Comp. Zool., Mem., vol. 34, no. 2, p. 53.
Salenia LAMBERT and THIÉRY, *1910*, Essai de nomenclature raisonnée des échinides, p. 210.

Genotype, *Cidarites scutiger* Goldfuss, 1829, from the Cenomanian of Europe, by monotypy. This species is described and figured by Cotteau (1861, p. 154, pl. 1036; pl. 1037, figs. 1–10).

SALENIA TUMIDULA Clark

Salenia tumidula CLARK, *1891*, Johns Hopkins Univ. Circ., vol. 10, no. 87, p. 75.
Salenia tumidula CLARK, *1915*, U. S. Geol. Survey, Mon. 54, p. 50, pl. 13, figs. 1a–j.

Occurrence.—Timber Creek, N. J.; Rancocas Creek, near Vincentown, N. J. (F. B. Meek, collector).

Geologic horizon.—Early Eocene, Vincentown sand.

Type.—Acad. Nat. Sci. Philadelphia, 1448.

SALENIA BELLULA Clark

Salenia bellula CLARK, *1891*, Johns Hopkins Univ. Circ., vol. 10, no. 87, p. 75.
Salenia bellula CLARK, *1915*, U. S. Geol. Survey, Mon. 54, p. 51, pl. 13, figs. 2a–g.

Occurrence.—Timber Creek, near Vincentown, N. J.

Geologic horizon.—Early Eocene, Vincentown sand.

Type.—Acad. Nat. Sci. Philadelphia, 1446.

Remarks.—There are no identified specimens of this species in the National Museum. The differences between *S. tumidula* and *S. bellula* as shown in Clark's drawings are not convincing.

SALENIA sp.

Disconnected plates apparently from a species of *Salenia* were collected by L. D. Toulmin from the Salt Mountain limestone half a mile north of Salt Mountain, Clarke County, Ala. In view of the close similarity of the fauna of the Salt Mountain limestone to that of the Vincentown sand of New Jersey, it would not be surprising if these fragments should prove to represent one of the species described from that formation.

Family CENTRECHINIDAE

Genus PSEUDODIADEMA Desor, 1855

Pseudodiadema DESOR, *1855*, Synopsis des échinides fossiles, fasc. 2, p. 63.
Pseudodiadema COTTEAU, *1862*, Paléontologie française, sér. 1, t. 7, p. 407.
Pseudodiadema COTTEAU, *1881*, idem, t. 10, pt. 2, p. 226.
Pseudodiadema LAMBERT and THIÉRY, *1910*, Essai de nomenclature raisonnée des échinides, fasc. 3, p. 178.

Genotype, *Cidarites pseudodiadema* Lamarck (1816, p. 59; 1840, p. 385), Jurassic of Europe, by original designation. Desor identifies this species as *Diadema hemisphaericum* Agassiz, under which name he describes and figures it (1855, p. 68, pl. 13, fig. 4). It has also been described and figured as *Pseudodiadema pseudodiadema* by Cotteau (1882, p. 330, pls. 353–355), but some of Cotteau's figures, particularly plate 353, may not represent the same species as that figured by Desor.

The distinguishing characteristics of *Pseudodiadema* as described by Desor are: the equal size of its primary tubercles in the ambulacral and interambulacral areas, the crenulation and perforation of its tubercles, which form two, four, or six rows in the interambulacral areas and two in the ambulacral areas, its single rows of pore pairs, and its finely striated but not serrated spines. Desor's figured specimen of the genotype lacks the apical system.

Desor's figure shows little or no duplication of the pores at the peristome, though his description of the genotype says that its

pores are more or less doubled on the periphery of the peristome, which is very wide and deeply notched. Cotteau's drawings on plates 354 and 355 answer to this description, but figure 3, plate 353, shows a strong multiplication of the pores for some distance away from the peristome. The original of this figure came from a lower horizon than Desor's specimen and may represent a different species.

PSEUDODIADEMA DIATRETUM (Morton)

Cidaris diatretum MORTON, *1833*, Am. Jour. Sci., ser., 1, vol. 23, p. 294.
Cidarites diatretum MORTON, *1834*, Synopsis organic remains Cretaceous, p. 75, pl. 10, fig. 10.
Pseudodiadema diatretum DESOR, *1855*, Synopsis des échinides fossiles, p. 73.
Pseudodiadema diatretum COTTEAU, *1864*, Paléontologie française, sér. 1, t. 7, p. 519.
Pseudodiadema diatretum CLARK, *1893*, U. S. Geol. Survey, Bull. 97, pp. 46, 47, pl. 13, figs. 1a–f.
Pseudodiadema diatretum CLARK, *1915*, idem, Mon. 54, p. 56, pl. 19, figs. 1a–f.
Polydiadema diatretum LAMBERT and THIÉRY, *1910*, Essai de nomenclature raisonnée des échinides, fasc. 3, p. 190.

Occurrence.—Gloucester (type), Timber Creek, and Vincentown, N. J.

Geologic horizon.—Early Eocene, Vincentown sand.

Type.—Acad. Nat. Sci. Philadelphia 1471.

Remarks.—There are no authentic specimens of this species in the United States National Museum. The type as figured by Clark appears to be congeneric with *Pseudodiadema hemisphaericum* as described by Desor, but its peristome is much smaller. Neither Clark's figure nor description indicates any duplication of the pores at the peristome, though the plates adjacent to the peristome contain four instead of three sets of pores.

PSEUDODIADEMA? AMERICANUM (Clark)

Gagaria americana CLARK, *1915*, U. S. Geol. Survey, Mon. 54, p. 159, pl. 73, figs. 8a–b.
Thylechinus americanus LAMBERT and THIÉRY, *1925*, Essai de nomenclature raisonnée des échinides, fasc. 8, p. 567.

Occurrence.—The Rocks, sec. 35, T. 9 N., R. 1 E., Clarke County, Ala.

Geologic horizon.—Eocene, Ocala limestone, or Oligocene, Vicksburg group.

Type.—Johns Hopkins University, Aldrich collection.

Remarks.—This species is known only from the type specimen. Its perforate tubercles remove it from *Gagaria*.

Family ARBACIIDAE

KEY TO THE EAST-AMERICAN ARBACIIDAE

1. Ambulacral areas surrounded by a nodular thread; tubercles not extending above ambitus on interambulacral areas (Eocene) ..... *Coelopleurus.*
   2. Tubercles extending to apical end of ambulacral areas ..... *C. infulatus.*
   2. Tubercles not extending to apical end of ambulacral areas ..... *C. carolinensis.*
1. Ambulacral areas not surrounded by a nodular thread; outer row of tubercles on interambulacral areas extending above ambitus ..... *Arbacia.*
   2. More than 12 plates in adult interambulacral column.
      3. Test depressed ..... *A. improcera.*
      3. Test not depressed ..... *A. sloani.*
   2. Not more than 12 plates in adult interambulacral column.
      3. Miliary areas smooth ..... *A. aldrichi.*
      3. Miliary areas not smooth.
         4. Tubercles on median part of interambulacral areas extending above ambitus ..... *A. rivuli.*
         4. Tubercles on median part of interambulacral areas not extending above ambitus.
            5. Ocular plates having one tubercle; test depressed ..... *A. waccamaw.*
            5. Ocular plates without tubercles; test not depressed ..... *A. punctulata.*

Genus COELOPLEURUS Agassiz, 1840

Coelopleurus AGASSIZ, *1840*, Catalogus systematicus ectyporum echinodermatum fossilium musei Neocomensis, p. 12.
Coelopleurus AGASSIZ and DESOR, *1847*, Catalogue raisonné, p. 52.
Coelopleurus DESOR, *1858*, Synopsis des échinides fossiles, p. 96.
Coelopleurus A. AGASSIZ, *1872*, Harvard College, Mus. Comp. Zoology, Mem., vol. 3, no. 7, p. 267.
Coelopleurus POMEL, *1883*, Classification méthodique et genera des échinides vivants et fossiles, p. 87.
Coelopleurus DUNCAN and SLADEN, *1884*, Paleontologia Indica, ser. 14, vol. 1, pt. 3, p. 251.
Coelopleurus COTTEAU, *1893*, Paléontologie française, sér. 1, t. 2, p. 544.
Coelopleurus AGASSIZ and CLARK, *1908*, Harvard

College, Mus. Comp. Zool., Mem., vol. 34, no. 2, p. 82.

Coelopleurus LAMBERT and THIÉRY, *1914*, Essai de nomenclature raisonnée des échinides, p. 264.

Genotype, *Cidaris coronalis* Leske (1778, p. 136, pl. 8, figs. A, B), from the upper Eocene of France. This species has been described and figured by Cotteau (1893, p. 560, pl. 335) and (under the name *C. equis*) by Desor (1858, p. 97, pl. 16, figs. 4–6), and by Duncan and Sladen (1884, p. 251, pl. 39, figs. 3–8).

Coelopleurus differs from *Arbacia* in the absence of all tubercles from the interambulacral areas above the ambitus, whereas in *Arbacia* the outer rows and rarely also the other rows continue to the summit. In *Coelopleurus* a granular thread extends from the hollow behind each of the outer rows of tubercles at the ambitus to the ocular plates. This thread is wanting in *Arbacia*. *Coelopleurus* is further distinguished by the presence of five pits or pores along a line adjacent to the peristome and bisecting the ambulacral area. In *Arbacia* there is only one. The pore pairs in *Coelopleurus* are not crowded at the peristome as in *Arbacia*.

Agassiz and Clark recognize five Recent species of *Coelopleurus*, two from the Philippines, one from the East Indies, one from New Britain, and one, *C. floridanus* A. Agassiz, from the West Indies. The holotype of the last is a broken spine dredged from the Straits of Florida.

COELOPLEURUS INFULATUS (Morton)

Echinus infulatus MORTON, *1833*, Am. Jour. Sci., ser. 1, vol. 24, p. 131, pl. 10, fig. 7.

Coelopleurus infulatus CLARK and TWITCHELL, *1915*, U. S. Geol. Survey, Mon. 54, p. 117, pl. 56, figs. 1a–i.

Occurrence.—South Carolina (Morton); Pooshee Plantation, Berkeley County, S. C. (Toumey).

Geologic horizon.—Eocene, Santee limestone.

Type.—Acad. Nat. Sci. Philadelphia 1076.

Remarks.—There are no identified specimens of this species in the United States National Museum. The type probably came from somewhere along the Santee Canal, perhaps from Pooshee Plantation, where Tuomey (1848 p. 156) reports the species associated with Eocene fossils.

COELOPLEURUS CAROLINENSIS Cooke, n. sp.

Plate 2, figures 1–3

Test small, depressed, circular. Oculogenital ring dicyclic; genital pores large, periproct central, subpentagonal, bordered by small tubercles. Ambulacral areas with two rows of large imperforate conical tubercles extending from the peristome to a point about midway between the ambitus and the apical end; several plates at the apical end are bare except for granules bordering the inner edges of the poriferous zones; pore pairs wide and aligned at apical end, narrower and curved around tubercles elsewhere, apparently not horizontal at the peristome; three pairs of pores in each plate; a line of five pits bisects the ambulacral area adjacent to the peristome at the ambitus. Interambulacral areas nearly one and one-half times as wide as the ambulacral areas; two central rows of large conical imperforate tubercles extend from the peristome to the ambitus, and there are two marginal rows of slightly smaller tubercles on the base; granules surround the tubercles and the lower part of the otherwise bare area above them; a submarginal row of confluent granules on each side of each interambulacral area above the ambitus terminates at the rosette of granules on the adjoining ocular plates. Peristome large; gill slits shallow, with calluses extending well onto the interambulacral area.

Diameter, 14.2 mm.; height, 7.2 mm.; diameter of peristome, 6.4 mm.

Occurrence.—County rock quarry near Wilmington, N. C. (L. W. Stephenson, collector).

Geologic horizon.—Late Eocene, Castle Hayne marl.

Holotype.—U. S. Nat. Mus. 166500.

Remarks.—This species is represented by only one small specimen, which may prove to be an immature *C. infulatus* (Morton). Its most conspicuous difference from *C. infulatus* is its lack of tubercles at the apical ends of the ambulacral areas.

Genus ARBACIA Gray, 1835

Arbacia GRAY, *1835*, Zool. Soc. London, Proc.,

pt. 3, p. 58. Cites *Echinus pustulosus* Lamarck and *Echinus punctulatus* Lamarck.
Arbacia A. AGASSIZ, *1872*, Harvard College, Mus. Comp. Zool., Mem., vol. 3, no. 7, pp. 90, 263.
Arbacia LOVEN, *1887*, K. svenska vetensk. akad., Handl., Bihang, bind 13, pt. 4, no. 5, p. 81.
Arbacia AGASSIZ and CLARK, *1908*, Harvard College, Mus. Comp. Zool., vol. 34, no. 2, p. 67.
Arbacia LAMBERT and THIÉRY, *1914*, Essai de nomenclature raisonnée des échinides, p. 270.

Genotype, *Cidaris pustolosa* Leske, living in the Mediterranean and off Liberia and Brazil (Agassiz), designated by Agassiz and Clark (1908).

ARBACIA PUNCTULATA (Lamarck)

Echinus punctulatus LAMARCK, *1816*, Histoire naturelle des animaux sans vertèbres, p. 47; *1840*, idem, 2d ed., vol. 3, p. 363.
Arbacia punctulata GRAY, *1835*, Zool. Soc. London, Proc., p. 58.
Anapesus carolinus HOLMES, *1860*, Post-Pleiocene fossils of South Carolina, p. 5, pl. 2, fig. 2.
Arbacia punctulata A. AGASSIZ, *1872*, Harvard College, Mus. Comp. Zool., Mem., vol. 3, no. 7, pp. 91, 263, pl. 2, fig. 4; pl. 5, figs. 1–18.
Arbacia punctulata LOVEN, *1887*, K. svenska vetensk. akad., Handl., Bihang, bind 13, pt. 4, no. 5, p. 121.
Arbacia punctulata AGASSIZ and CLARK, *1908*, Harvard College, Mus. Comp. Zool., Mem., vol. 34, no. 2, p. 71, pl. 47, figs. 17–19; pl. 48, figs. 1–9.

Occurrence.—Living in the Atlantic Ocean and Gulf of Mexico from Long Island Sound to western Florida (Agassiz); fossil at Charleston, Simmons Bluff, and Wando, S. C. (Holmes).

Geologic horizon.—Recent and Pleistocene, Pamlico formation.

ARBACIA WACCAMAW Cooke, n. sp.
Plate 1, figures 1–3

Echino-cidaris sp. indet. TUOMEY and HOLMES, *1852*, Pleiocene fossils of South Carolina, fasc. 1, pl. 2, figs. 5, 5a.

Test of medium size, circular; upper surface depressed, subconical; lower surface evenly rounded. Periproct large, central, suboval. Oculogenital ring dicyclic; genital plates large, corrugated to granular, pores large; ocular plates smaller, each with a large central tubercle. Ambulacral areas with two rows of imperforate tubercles, which are large on the lower surface but which are reduced to granules at the apical ends; pore pairs three in each plate, uniserial and straight on the upper surface, curved around the tubercles on the ambitus, and almost horizontal at the peristome. Interambulacral areas twice as wide as the ambulacral areas; with four rows of large imperforate tubercles on the base and ambitus only, the lateral rows extending to the apex; miliary spaces covered with large close-set granules, many of which on the median part of the upper surface are longitudinally elongated, giving the tubercle-free areas a corrugated appearance; plates wide. Peristome large, subpentagonal; gill slits broad and very shallow.

Diameter, 34 mm.; height, 17.4 mm.; diameter of peristome, 17 mm.

Occurrence.—Intracoastal Waterway canal about 4½ miles southwest of Little River, Horry County, S. C. (station 13377, spoil bank of the canal, C. W. Cooke, collector, holotype; S. F. Blake, collector).

Geologic horizon.—Pliocene, Waccamaw formation.

Holotype.—U. S. Nat. Mus. 498888.

Remarks.—The holotype of this species is more depressed than *Arbacia punctulata*, its peristome is somewhat narrower, and each ocular plate has a large tubercle, which is represented in *A. punctulata* by a rosette of small granules. Its miliary areas are coarsely rugose, in contrast with the finely, evenly papillate surface of *A. punctulata*. The poriferous zones, like those of *A. punctulata*, are much wider than those of *A. aldrichi*. The interambulacral plates resemble those of *A. punctulata* but are much higher than those of *A. improcera*.

ARBACIA RIVULI Cooke, n. sp.
Plate 1, figures 4–6

Test medium-sized; outline circular, tumid above, evenly rounded below the ambitus. Periproct central, suboval. Oculogenital ring dicyclic; genital pores large; each ocular plate having a large central tubercle. Ambulacral areas moderately wide; poriferous zones nearly half as wide as the interporiferous zones; pores conjugate; pairs of pores three to a plate, in a single straight line above the ambitus, in curved groups at the ambitus, and presumably horizontal around the peristome; interporiferous zones decorated with two continuous rows of tubercles, one tubercle on each plate; miliary areas granular. Interambulacral areas twice as wide as the ambulacral areas, decorated with four rows of tubercles, of which the

marginal rows extend to the oculogenital ring, but the inner rows not quite so far; miliary areas granular. Tubercles on ambulacral and interambulacral areas approximately the same size. Peristome wide, subpentagonal.

Height, 19 mm.; width, 36 mm. Diameters of periproct, 4.5 and 3.5 mm. Width of peristome, about 17 mm.

Remarks.—*Arbacia rivuli*, which is represented by only one specimen, differs from the Recent *A. punctulata* in the presence of tubercles on the ocular plates and on the median parts of the interambulacral areas above the ambitus. Its tubercles are smaller. Its periproct and oculogenital ring resemble *A. waccamaw*, with which it is associated, but its peristome is larger, it is more inflated, and it lacks the conspicuous bare areas on the upper surface.

Occurrence.—Intracoastal Waterway canal about 4½ miles southwest of Little River, Horry County, S. C. (station 13377, spoil bank of the canal, C. W. Cooke, collector).

Geologic horizon.—Pliocene, Waccamaw formation.

Holotype.—U. S. Nat. Mus. 498887.

ARBACIA ALDRICHI (Clark)

Coelopleurus aldrichi CLARK, *1915*, U. S. Geol. Survey, Mon. 54, p. 158, pl. 73, figs. 6a–b, 7a–c.

Occurrence.—Perdue Hill, Monroe County, Ala. (type, T. H. Aldrich, collector); Patton Creek, Wayne County, Miss. (station 14287, W. C. Mansfield and F. S. MacNeil, collectors).

Geologic horizon.—Late Oligocene and early Miocene, Chickasawhay marl.

Type.—Aldrich collection, Johns Hopkins University, Baltimore, Md.

Remarks.—*Arbacia aldrichi* is represented in the United States National Museum by only one fragment, from Patton Creek, Miss., which shows the pentagonal outline and the decoration of the type as figured by Clark. Mr. MacNeil refers the bed from which he obtained it to the upper part of the Chickasawhay marl, the part tentatively correlated with the basal Miocene Tampa limestone of Florida. The bed in which the holotype was found is not recorded, but it probably is the lower, typical (Oligocene) part of the Chickasawhay marl, for Miocene beds are not known at Perdue Hill.

The species is referred to *Arbacia* rather than to *Coelopleurus* because its ambulacral areas appear to be proportionally narrower than in *Coelopleurus*, and the tubercles on them are smaller than on the interambulacral areas, as in *Arbacia*. Moreover, the outer rows of tubercles on the interambulacral areas extend to the summit, as in *Arbacia*.

ARBACIA SLOANI (Clark)

Coelopleurus sloani CLARK, *1915*, U. S. Geol. Survey, Mon. 54, p. 181, pl. 84, figs. 5a–b.

Occurrence. Bostick Landing, Pee Dee River, Florence County, S. C. (L. W. Stephenson, collector).

Geologic horizon.—Late Miocene, Duplin marl.

Holotype.—U. S. Nat. Mus. 166488.

Remarks.—This species is known only from the somewhat worn figured holotype and a smaller, much corroded specimen bearing the same catalogue number. *C. sloani* may be a synonym of *A. improcera*, which occurs at approximately the same geologic horizon. Its tubercles, though worn, retain traces of vertical corrugation like that of the Virginian species, and its miliary areas are similarly granulated. Its interambulacral plates are transversely elongated, like those of *A. improcera*. The most noticeable difference is the greater height of *C. sloani*—a feature that may be variable in the species.

ARBACIA IMPROCERA (Conrad)
Plate 1, figures 7–9

Echinus improcerus CONRAD, *1843*, Acad. Nat. Sci. Philadelphia, Proc., ser. 1, vol. 1, p. 310.
Coelopleurus improcerus CLARK and TWITCHELL, *1915*, U. S. Geol. Survey, Mon. 54, p. 180, pl. 84, figs. 4a–c.

Occurrence.—James River near Smithfield, Va. (Conrad); J. T. Williams' marl pit on Smith Creek ½ mile below the dam of the Suffolk, Va., waterworks (figured specimen, M. W. Twitchell, collector); bank of Nansemond River rising above the tidal flats at Suffolk, Va. (station 10201, W. C. Mansfield, collector).

Geologic horizon.—Miocene, Yorktown formation.

Type.—Probably Acad. Nat. Sci. Philadelphia.

Figured specimen.—U. S. Nat. Mus. 166-487.

Remarks.—*Arbacia improcera* is represented in the United States National Museum by three individuals—the mature specimen figured by Clark and Twitchell, a smaller one from the same place, and a very small one from the Nansemond River. The oculogenital ring is dicyclic. Each ocular plate bears a tubercle and large elongated granules. Some of the genital plates of the small specimens are without pores but bear granules and one tubercle. The granules persist in the mature specimen, but the tubercles are not apparent. The tubercle-free parts of the interambulacral areas are decorated with coarse granules, many of which are elongated longitudinally. The large tubercles on the ambitus consist of a large round imperforate mamelon on a high corrugated, truncated base. The ambulacral pore pairs, three in each plate, form a single straight line from the apex to the beginning of the large tubercles, around which they curve and become increasingly deflected until they become nearly horizontal at the peristome. The gill slits are very broad and very shallow, but their calluses extend far upon the interambulacral areas. The test is very much depressed—a feature that evidently suggested the specific name.

Family ECHINIDAE

Genus MICROSOMA Cotteau, 1886

Microsoma COTTEAU, *1886*, Soc. zool. France, Bull., t. 11, p. 715.

Genotype, *Cyphosoma crozieri* Cotteau (1885, Soc. zool. France, t. 10, p. 552, pl. 12, figs. 8–13; 1886, idem, t. 11, p. 716, pl. 23, figs. 14–17), Senonian of France, by monotypy.

Lambert and Thiéry (1910, p. 219) regard *Microsoma* as a synonym of *Coptosoma* Desor, 1855 (not Laporte, 1833), which latter name they later (1914, p. 274) propose to replace by *Porosoma* Cotteau, 1856. However, according to Desor the genotype of *Coptosoma* Desor has its pore pairs in arcs of seven instead of the three or four shown in Cotteau's figures of *Microsoma crozieri*, which, however, may represent immature individuals.

MICROSOMA SPECIOSUM (Clark)
Plate 3, figures 1–4

Cyphosoma speciosum CLARK, *1891*, Johns Hopkins Univ. Circ., vol. 10, no. 87, p. 76.
Coptosoma speciosum LAMBERT and THIÉRY, *1910*, Essai de nomenclature raisonnée des échinides, fasc. 3, p. 219.
Coptosoma speciosum CLARK, *1915*, U. S. Geol. Survey, Mon. 54, p. 61, pl. 19, figs. 3a–h.

Occurrence.—Timber Creek, N. J. (type); Rancocas Creek, Vincentown, N. J. (F. B. Meek, collector).

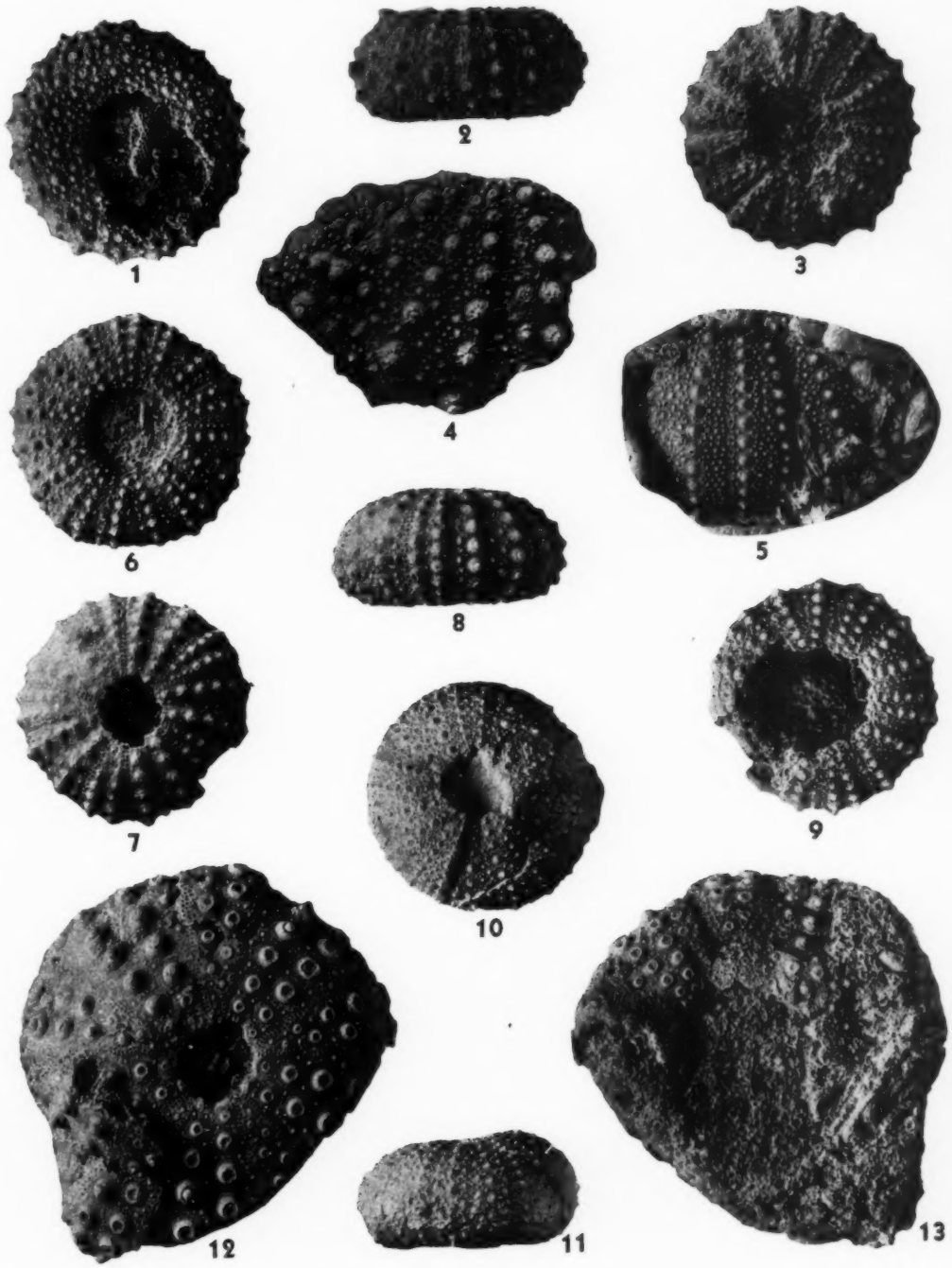
Geologic horizon.—Early Eocene, Vincentown sand.

Type.—Acad. Nat. Sci. Philadelphia 1468.

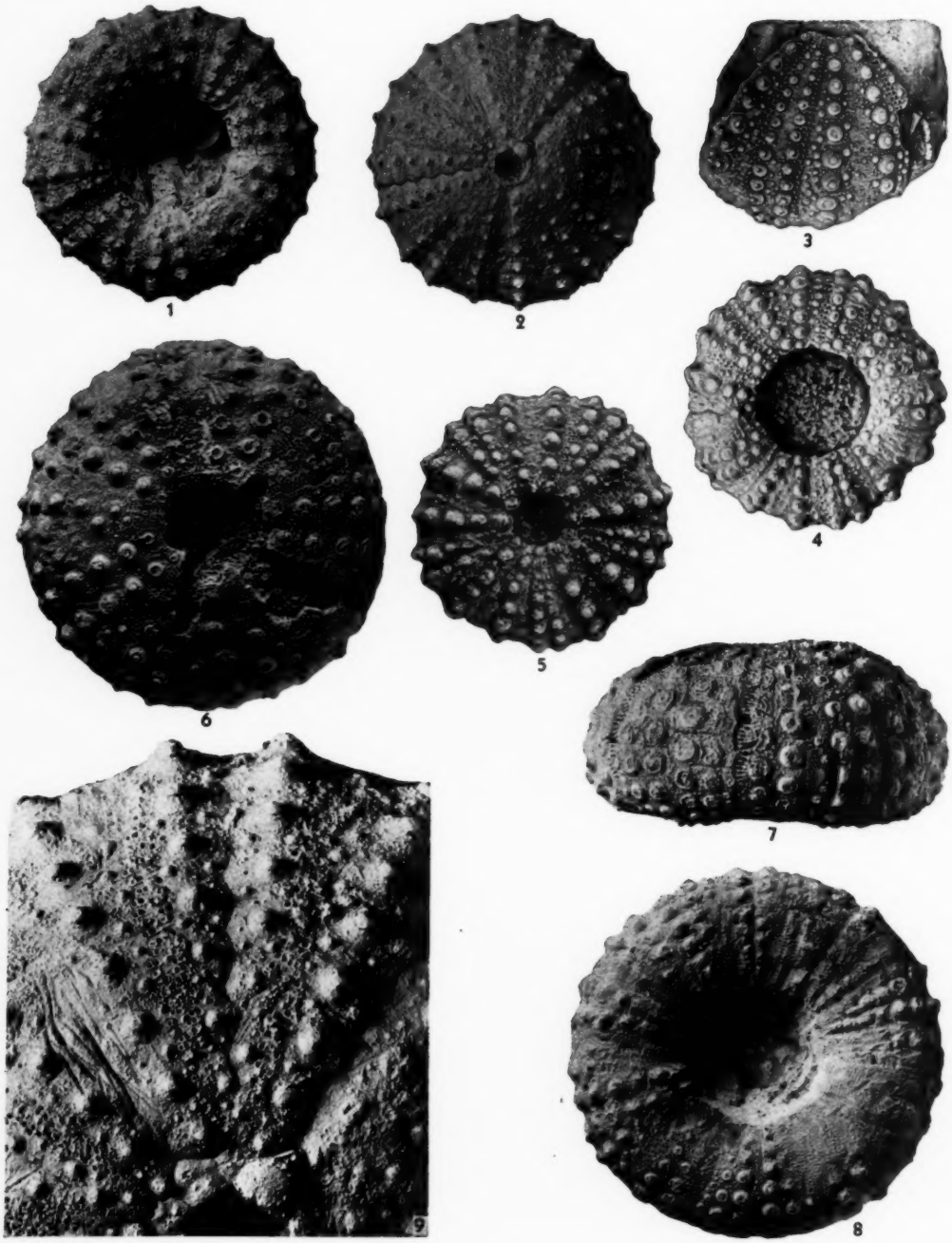
Remarks.—This species is represented in the United States National Museum by one imperfect individual and by a fragment of a larger specimen, both of which are figured. These were originally labeled *Pseudodiadema diatretum*, from which species they differ in having imperforate tubercles. They show four pairs of pores in each plate except near the apex and possibly near the peristome, where there appear to be three. The pore pairs are uniserial throughout, but the groups are slightly inclined. Clark's description specifies three pairs of pores in each plate, but one of his drawings of the type (fig. 3*f*) shows four. This species may be more closely related to *Glyptocidaris* A. Agassiz, 1868, than to *Microsoma*, but *G.*

EXPLANATION OF PLATE 3

FIGS. *1–4—Microsoma speciosum* (Clark), Vincentown, N. J., U. S. Nat. Mus. 29468. *1–3*, Lower, side, and upper views of same individual, ×1½. *4*, Fragment, ×3. (p. 12)
5—Stirechinus? sp., Dukes Siding, S. C., guttapercha squeeze, U. S. Nat. Mus. 498886, ×1½. (p. 14)
6–9—Thylechinus (*Gagaria*) *mossomi* Cooke, n. sp., Blackwater Creek, Fla., U. S. Nat. Mus. 498884, ×1½. *6*, Lower view. *7–9*, Upper, side, and lower views of a different individual. (p. 13)
10, 11—Psammechinus floralanus Cooke, n. sp., holotype, Adams Crossroads, Ala., U. S. Nat. Mus. 498891, upper and side views, ×1½. (p. 15)
12, 13—Phymotaxis mansfieldi Cooke, n. sp., syntype, Brooksville, Fla., U. S. Nat. Mus. 372868, upper and lower views, ×1½. (p. 18)



Cooke, Cenozoic Echinoids



Cooke, Cenozoic Echinoids

crenularis, the genotype, has five pairs of pores in each plate.

Genus THYLECHINUS Pomel, 1883

Thylechinus POMEL, *1883*, Classification méthodique et genera des échinides vivants et fossiles, p. 91.

Thylechinus LAMBERT and THIÉRY, *1910*, Essai de nomenclature raisonnée des échinides, p. 214.

Genotype, *Cyphosoma saïd* Peron and Gauthier (1881, in Cotteau, Peron, and Gauthier, 1873–1883, t. 2, p. 172, pl. 19, figs. 3–10), from the Senonian of Algeria, designated by Lambert and Thiéry.

Subgenus GAGARIA Duncan, 1889

Micropsis (*Gagaria*) DUNCAN, *1889*, Linnean Soc. London, Jour., Zoology, vol. 23, p. 91.

Genotype, *Micropsis venustula* Duncan and Sladen (1884, p. 119, pl. 22, figs. 1–7), Eocene (Khirthar) of Sind, by monotypy.

Gagaria is regarded by Lambert and Thiéry as a synonym of *Thylechinus*, but the differences may be worthy of at least subgeneric rank. The oculogenital ring of *Thylechinus saïd* is dicyclic, but in *Gagaria venustula* ocular I reaches the periproct. This seems to be the normal location in *Gagaria*. *Gagaria* has three pairs of pores in each compound plate, whereas *Micropsis* has four.

THYLECHINUS (GAGARIA) SALIS
Cooke, n. sp.
Plate 2, figures 12–14

Test small, subhemispherical, slightly concave below. Madreporite tumid; ocular I (broken off) apparently reached the periproct, but oculars II and III do not; other ocular and genital plates broken from type. Ambulacral areas nearly half as wide as interambulacral areas; pores small, round, pairs in uniserial straight lines, three pairs in each compound plate. Tubercles apparently imperforate and not crenulate; two rows of primary tubercles on ambulacral and interambulacral areas; two or more rows of smaller tubercles on ambulacral areas and four or more on interambulacral areas. Peristome small, nearly round, strongly notched; notches callous.

Diameter, 20 mm.; height, 12.3 mm.; diameter of peristome, 8 mm.

Occurrence.—Salt Mountain, 5 miles south of Jackson, Clarke County, Ala. (station 3643, near base of section at southern end, T. W. Vaughan, collector).

Geologic horizon.—Early Eocene, Salt Mountain, limestone.

Type.—U. S. Nat. Mus. 166497.

Remarks.—This species is known from only one badly worn specimen. Most of its primary tubercles show no sign of perforation, but a few have marks that may be perforations but are probably blemishes.

THYLECHINUS (GAGARIA) MOSSOMI
Cooke, n. sp.
Plate 1, figures 6–9; plate 2, figure 16; plate 4, figures 3–5

Test rather small, subhemispherical, upper surface slightly flattened, lower surface rounded below the ambitus and slightly concave around the large notched peristome. Ambulacral areas narrower than interambulacral areas. Ambulacral pores large; pairs uniserial, nearly straight, but each group of three pore pairs slightly curved around a large tubercle; each pore pair divided by a raised septum. Interporiferous areas provided with two rows, about 20 in each row, of moderately strong, crenulated, imperforate primary tubercles and two shorter rows of smaller tubercles. Interambulacra provided with two rows, about 16 in each row, of primary tubercles about equal in size to those on the ambulacra and with several rows of smaller tubercles, which are most numerous on the ambitus.

Height of larger syntype, a fragment, 20

EXPLANATION OF PLATE 4

FIGS. *1, 2, 9—Phymosoma dixie* Cooke, n. sp., holotype, Clara, Fla., U. S. Nat. Mus. 372867. *1, 2*, Lower and upper views, ×1. *9*, Part of upper surface, ×3¾. (p. 17)

3–5—Thylechinus (*Gagaria*) *mossomi* Cooke, n. sp., syntypes, Blackwater Creek, Fla., U. S. Nat. Mus. 372885. *3*, Fragment, ×1½. *4, 5*, Lower and upper views of young individual, ×2⅔. (p. 13)

6–8—Phymotaxis mansfieldi Cooke, n. sp., syntype, Brooksville, Fla., U. S. Nat. Mus. 372868, upper, side, and lower views, ×1. (p. 18)

mm.; diameter of smaller syntype, 15 mm.; height, 8.2 mm.

Occurrence.—Excavated from Blackwater Creek at crossing at Seaboard Airline Railway and highway, Hillsborough County, Fla. (station 11116, type, C. W. Cooke and Stuart Mossom, collectors; Helen I. Tucker Rowland, collector); quarry of Florida Rock Products Company 0.75 mile southwest of Brooksville, Hernando County, Fla. (station 11113, C. W. Cooke and Stuart Mossom, collectors; station 12322, W. C. Mansfield and F. S. MacNeil, collectors; Florida Geological Survey station I-1605, G. M. Ponton, collector); abandoned quarry 5 miles west of Brooksville, Fla. (station 12318, W. C. Mansfield and G. M. Ponton, collectors).

Geologic horizon.—Late Oligocene, Suwannee limestone.

Syntypes.—U. S. Nat. Mus. 372885.

Remarks.—This species seems to be common at the type locality, but it is not generally well preserved. Only one individual, collected by Mrs. Rowland, retains the apical system. The madreporite is inflated and ocular I penetrates to the periproct. Some individuals have a subpentagonal outline, in this respect resembling *Gagaria venustula*, the genotype.

Thylechinus (Gagaria) chickasawhay Cooke, n. sp.
Plate 2, figures 17a-d

Test of medium size. Oculogenital ring and peristome unknown. Ambulacral areas with two rows of large crenulate, imperforate tubercles, each tubercle surrounded by a squared ring of small tubercles; pore pairs uniserial, nearly straight, three pairs in each compound plate; pores of each pair separated by a granule. Interambulacral areas wider, with two contiguous median rows of crenulate, imperforate large tubercles and one row of smaller tubercles on each margin; each large tubercle enclosed in a ring of little tubercles. Detached spines long, slender, cylindrical, slightly swollen near the tip, smooth when perfect but longitudinally striated when eroded. Larger spines flattened, spoon-shaped.

Occurrence.—Chickasawhay River above the highway bridge 2½ miles south of Waynesboro, Miss. (station 13388, C. Wythe Cooke, collector).

Geologic horizon.—Oligocene, Chickasawhay marl.

Syntypes.—U. S. Nat. Mus. 498885.

Remarks.—This species is known only from fragments of the test and from detached spines. The name is an Indian word pronounced Chick-a-saw-háy.

Genus Stirechinus Desor, 1856

Stirechinus Desor, *1856*, Synopsis des échinides fossiles, fasc. 3, p. 131, pl. 17 *bis*, figs. 6, 7.
Stirechinus Lambert and Thiéry, *1914*, Essai de nomenclature raisonnée des échinides, p. 244.

Genotype, *Echinus scillae* Desmoulins, from the Pliocene of Italy, by monotypy.

Desor characterizes the genus thus: Swollen, hemispherical urchins, imperforate, and not crenulate, forming prominent vertical rows. As the intermediate spaces are more or less sunken, the tubercles appear to stand on carinae, the most conspicuous feature of the genus. The sutures of the plates are very plain.

Stirechinus? sp.
Plate 3, figure 5

This species is known only from the mold of a fragment. Its test is large and globular. The ambulacral areas are little more than half as wide as the interambulacral areas. The pore pairs apparently are in groups of three, slightly inclined. There are two rows of small, simple, imperforate primary tubercles on each ambulacral area and two on each interambulacral area. The intermediate spaces are filled with close-set smaller tubercles or granules of various sizes.

The shape and decoration of this species resemble *Stirechinus*, but the carination along the rows of primary tubercles that suggested the name of the genus is less conspicuous than in the genotype.

Occurrence.—From a well at Duke Siding, 2¾ miles north of Gifford, Hampton County, S. C. (station 10409, C. W. Cooke, collector).

Geologic horizon.—Early Miocene, Hawthorn formation.

Figured specimen.—U. S. Nat. Mus. 498886.

Genus Progonechinus Duncan and Sladen, 1882

Progonechinus Duncan and Sladen, *1882*, Paleontologia Indica, ser. 14, vol. 1, pt. 3, p. 43.

Progonechinus LAMBERT and THIÉRY, *1910*, Essai de nomenclature raisonnée des échinides, fasc. 3, p. 229.

Genotype, *P. eocenicus* Duncan and Sladen (1882, p. 42, pl. 10, figs. 1–4), from the Eocene Ranikot limestone of Sind, by monotypy.

PROGONECHINUS PRETIOSUS (Clark)
Plate 2, figures 4–6

Orthechinus pretiosus CLARK, *1915*, U. S. Geol. Survey, Mon. 54, p. 118, pl. 56, figs. 2a–b, 1915.

Occurrence.—Near Dead Level, Choctaw County, Ala. (station 2893, Charles Schuchert, collector).

Geologic horizon.—Eocene, Jackson group.

Type.—U. S. Nat. Mus. 146455.

Remarks.—When described and figured by Clark, the type and only known representative of this species was covered by a thin coating of soft matrix, which concealed many details of structure and ornamentation but which has since been removed. The oculogenital ring is dicyclic. Each genital plate has one small tubercle near the periproct; most of the remainder of its surface is covered with confluent granules. Many of the granules on both the ambulacral and the interambulacral areas are confluent to such an extent as to form coarse ridges, which generally radiate away from the tubercles. The lower surface is evenly rounded from the ambitus to the peristome, which occupies about one-third of the width of the test and which is notched by shallow gill slits.

Genus PSAMMECHINUS Agassiz and Desor, 1846

Echinus (*Psammechinus*) AGASSIZ and DESOR, *1846*, Annales Sci. nat. (zool.), sér. 3, t. 6, p. 368; (1847, reprint, p. 64).

Psammechinus DESOR, *1855*, Synopsis des échinides fossiles, p. 118.

Psammechinus POMEL, *1883*, Classification méthodique et genera des échinides vivants et fossiles, p. 84.

Psammechinus LAMBERT and THIÉRY, *1910*, Essai de nomenclature raisonnée des échinides, p. 239.

Psammechinus H. L. CLARK, *1912*, Harvard College, Mus. Comp. Zool., Mem., vol. 34, no. 4, p. 242.

Genotype, *Echinus miliaris* Gmelin, 1788, living off Norway and in the English Channel, designated by Lambert and Thiéry, 1910.

PSAMMECHINUS SANTEE COOKE, n. sp.
Plate 2, figures 7, 8

Test small, subhemispherical; upper surface slightly depressed, lower surface rounded. Ambulacral areas about half as wide as the interambulacral areas; pore pairs in inclined groups of three. Tubercles large, simple, with small imperforate mamelons, uniform in size, one on every plate; two rows on each ambulacral area and four rows on each interambulacral area. Genital plates large; each with a small tubercle between the pore and the periproct; madreporite inflated. Ocular plates apparently not reaching the periproct. Periproct ellipitical, enclosed by a ring of granules. Peristome large; gill slits wide and shallow. Spines long, slender, with fine serrate ribs.

Diameter of most complete syntype, 15.6 mm.; height, 11 mm.

Occurrence.—Orangeburg County, S. C., not far from the Santee River (station 4255, Earle Sloan, collector; probably 0.8 mile east of the Keith place, which is about 4½ miles northwest of Creston, now in Calhoun County).

Geologic horizon.—Medial Eocene? McBean formation?

Syntypes.—U. S. Nat. Mus. 498890.

Remarks.—This species is represented by impressions of several individuals, some with attached spines, in two lumps of porous sandstone. The exact locality is unknown. The matrix indicates that they may have come from the McBean formation. Sloan (1908, p. 329) records "numerous casts of an echinoderm" 0.8 mile east of the Keith place in Orangeburg (Calhoun) County.

PSAMMECHINUS FLORALANUS
Cooke, n. sp.
Plate 3, figures 10, 11

Test small, circular, depressed. Apical system wanting in the holotype. Ambulacral areas about three-quarters as wide as interambulacral areas; poriferous zones about half as wide as the interporiferous zones; pores arranged in diagonal groups of three pairs. Two rows of primary and two rows of secondary smooth imperforate tubercles on ambulacral and interambulacral areas; miliary areas covered with granules, which encircle the primary tubercles. Peristome

large; gill slits moderately shallow.

Height, 9 mm.; width 22 mm.; diameter of peristome, about 11 mm.

Occurrence.—Quarry of Florida Lime Products Co., ¼ mile northwest of Adams Crossroads, on lower Hacoda-Florala road, Covington County, Alabama (station 14604, F. S. MacNeil, collector).

Geologic horizon.—Late Oligocene, Suwannee limestone (possibly Byram).

Holotype.—U. S. Nat. Mus. 498891.

Remarks.—This species is represented by only one somewhat defective specimen. Its gill slits, though obscure, appear to be intermediate between the wide, shallow slits of *P. philanthropus* and the much narrower, deep slits of *Lytechinus variegatus*. It differs from other species referred to *Psammechinus* in that its tubercles are plainly of two sizes.

PSAMMECHINUS PHILANTHROPUS (Conrad)

Echinus philanthropus CONRAD, *1843*, Acad. Nat. Sci. Philadelphia, Proc., vol. 1, p. 310.
Psammechinus philanthropus CLARK and TWITCHELL, *1915*, U. S. Geol. Survey, Mon. 54, p. 181, pl. 84, figs. 6a–c.
Psammechinus (*Isechinus*) *philanthropus* LAMBERT and THIÉRY, *1925*, Essai de nomenclature raisonnée des échinides, p. 572.

Occurrence.—James River near Smithfield, Va. (type); C. F. Day's farm 1½ miles northeast of Smithfield, Va. (M. W. Twitchell, collector); Days Point, James River, Va. (station 14065, W. C. Mansfield and C. W. Mumm, collectors); 2½ miles northwest of Suffolk, Va. (station 10198, W. C. Mansfield, collector); York River, Va. (Johns Hopkins University, Clark and Twitchell's figured specimen); lower bed at Yorktown, Va. (Julia Gardner, collector). North Carolina (Emmons).

Geologic horizon.—Late Miocene, upper part of the Yorktown formation.

Type.—Acad. Nat. Sci. Philadelphia.

PSAMMECHINUS EXOLETUS McCrady

Psammechinus exoletus MCCRADY, *1855*, in TUOMEY and HOLMES, Pleiocene fossils of South Carolina, p. 4, pl. 2, fig. 6.
Psammechinus exoletus CLARK and TWITCHELL, *1915*, U. S. Geol. Survey, Mon. 54, p. 182.

Occurrence.—Smith's, Goose Creek, Berkeley County, S. C. (McCrady).

Geologic horizon.—Pliocene, Waccamaw formation.

Type.—Unknown.

Remarks.—There are no identified specimens of this species in the United States National Museum. The species is based upon a small fragment.

PSAMMECHINUS? OCALANUS Cooke, n. sp.
Plate 2, figures 9–11

Ambitus circular; test about half as high as wide; rather small. Ambulacral areas about half as wide as interambulacral areas; pore pairs arranged in straight diagonal groups of three; two rows of primary imperforate tubercles, extending to the apex. Interambulacral areas with four rows of primary tubercles, the two inner rows somewhat smaller than the outer, extending to the apex; miliary spaces at ambitus set with small tubercles or granules (remainder of test obscure). Peristome nearly half the total width, subpentagonal, deeply notched.

Diameter, 17.2 mm.; height, 8.5 mm.; diameter of peristome, 8 mm.

Occurrence.—Bainbridge, Ga., (station 13611, August Foerste, collector).

Geologic horizon.—Late Eocene, Ocala limestone.

Holotype.—U. S. Nat. Mus. 498889.

Remarks.—This species is based on one rather badly worn individual whose apical system and part of the ambitus are wanting. The ambulacral pores are arranged like those of *Psammechinus*, but the gill slits are much like those of *Lytechinus*, much deeper and narrower than in typical *Psammechinus*.

Genus LYTECHINUS A. Agassiz, 1863

Lytechinus A. AGASSIZ, *1863*, Harvard College, Mus. Comp. Zool., Bull., vol. 1, p. 24.
Lytechinus VERRILL, *1867*, Connecticut Acad. Arts and Sci., Trans., vol. 1, p. 302.
Lytechinus H. L. CLARK, *1912*, Harvard College, Mus. Comp. Zool., Mem., vol. 34, no. 4, p. 244.
Lytechinus LAMBERT and THIÉRY, *1914*, Essai de nomenclature raisonnée des échinides, fasc. 4, p. 246; 1925, idem, fasc. 8, p. 573.

Genotype, *Cidaris variegata* (part) Leske, 1778, living in the western Atlantic, designated by Verrill, 1867. This species should not be confused with *Tripneustes gratilla* (Linné), which Leske included in *C. variegata* and which Agassiz figured under the name *Hipponoë variegata*. (See Clark, 1912, p. 242, footnote.)

Lytechinus resembles *Psammechinus* but is larger and has much deeper gill slits.

LYTECHINUS VARIEGATUS (Leske)

Cidaris variegata (part) LESKE, *1778*, Additamenta ad Kleinii Echinodermata, p. 149, pl. 10, figs. B, C.
Echinus variegatus LAMARCK, *1840*, Histoire naturelle des animaux sans vertèbres, 2d ed., p. 365.
Echinus variegatus HOLMES, *1860*, Post-Pleiocene fossils of South Carolina, p. 4, pl. 2, fig. 1.
Lytechinus variegatus A. AGASSIZ, *1863*, Harvard College, Mus. Comp. Zool., Bull., vol. 1, p. 24.
Psilechinus variegatus LÜTKEN, *1864*, Naturh. Forening Kjöbenhavn, vidensk. Meddelelser, ser. 2, vol. 5, p. 93.
Toxopneustes variegatus A. AGASSIZ, *1872*, Harvard College, Mus. Comp. Zool., Mem., vol. 3, p. 168; *1873*, idem, p. 500, pl. 2, figs. 5, 6; etc.
Toxopneustes variegatus CLARK and TWITCHELL, *1915*, U. S. Geol. Survey, Mon. 54, p. 222.

Occurrence.—Agassiz reports this species from the Atlantic Ocean off Brazil, the West Indies, the Bermudas, and South Carolina. It is common in Boca Ceiga Bay, Florida. Holmes reports it fossil at Simmons Bluff and Charleston, S. C.

Geologic horizon.—Recent and Pleistocene, Pamlico formation.

Genus PHYMOSOMA d'Archiac and Haime, 1853

Cyphosoma AGASSIZ, *1840*, Catalogus systematicus . . . Musei Neocomensis, p. 11. Not MANNERHEIM, *1837*.
Cyphosoma AGASSIZ and DESOR, *1847*, Catalogue raisonné . . . des echinodermes, p. 47.
Cyphosoma COTTEAU, *1864*, Paléontologie française, sér. 1, t. 7, p. 567.
Cyphosoma DUNCAN and SLADEN, *1882*, Palaeontologia Indica, ser. 14, vol. 1, pt. 3, fasc. 2, p. 31.
Phymosoma D'ARCHIAC and HAIME, *1853*, Description des animaux fossiles de l'Inde, p. 197.
Phymosoma DESOR, *1858*, Synopsis des échinides fossiles, p. 86.
Phymosoma POMEL, *1883*, Classification méthodique et genera des échinides vivants et fossiles, p. 90.
Phymosoma LAMBERT and THIÉRY, *1910*, Essai de nomenclature raisonnée des échinides, fasc. 3, p. 222.

Genotype, *Echinus milleri* Demarest, 1825, = *Cidaris koenigi* Mantell, 1822, from the White Chalk, Upper Cretaceous, of England, designated by Lambert and Thiéry, 1910. This species is figured by Desor (1858, pl. 15, figs. 1–4) and by Cotteau (1864, p. 678, pls. 1167, 1168).

PHYMOSOMA DIXIE Cooke
Plate 2, figure 15;
plate 4, figures 1, 2, 9

Test moderately large, circular; upper surface gently arched; lower surface evenly rounded, concave near the peristome. Oculogenital ring monocyclic; madreporite large, tumid; other genital plates and ocular plates with sparsely scattered granules. Ambulacral areas as wide as interambulacral areas; pore pairs on upper surface biserial, nearly straight, 10 to 12 pairs on each plate, pore pairs of the two series alternating in position; pore pairs on lower surface in uniserial arcs, four or five pairs on each plate. Primary tubercles large, imperforate, crenulated, two rows on ambulacral areas and two on interambulacral areas. Miliary tubercles mammillated, near edges of plates on both ambulacral and interambulacral areas. Peristome large, circular; gill slits deeper than wide; peristomial edge of ambulacra bilobate.

Diameter, 43 mm.; height, 18 mm.; diameter of peristome, 18 mm.; width of ambulacral areas at ambitus, about 12.5 mm.; width of interambulacral areas, about 15.2 mm.

Occurrence.—Near Clara, Dixie County, Fla. (station 12747, highway east of Steinhatchee River, W. C. Mansfield and G. M. Ponton, collectors).

Geologic horizon.—Late Eocene, Ocala limestone.

Type.—U. S. Nat. Mus. 372867.

Remarks.—Except for minor details, this species agrees with Arnold and Clark's description of *Phymosoma peloria*, a species very abundant in the Spring Mount area, St. James Parish, Jamaica, and presumably Eocene, and may prove to be identical with it. The single individual upon which *P. dixie* is based is little more than half as large as the type of *P. peloria* but lies well within the range in size of that species.

Phymosoma dixie is less depressed and more deeply notched than the genotype as figured by Desor (1858, pl. 15). It also appears to have more pores in each plate, but the pores in Desor's figure are too obscure to be counted.

Genus TRIPNEUSTES Agassiz, 1841

Tripneustes AGASSIZ, *1841*, Mon. d'échinodermes, Introduction, p. 7.
Tripneustes H. L. CLARK, *1912*, Harvard College, Mus. Comp. Zool., Mem., vol. 34, no. 4, p. 285.
Tripneustes LAMBERT and THIÉRY, *1914*, Essai de nomenclature raisonnée des échinides, fasc. 4, p. 248.

Genotype, *Echinus ventricosus* Lamarck, 1816, = *Cidaris esculenta* Leske, 1778, living in the West Indian region, by original designation.

TRIPNEUSTES ESCULENTA (Leske)

Cidaris esculenta LESKE, *1778*, Additamenta ad Kleinii Echinodermata, p. 74 (name on p. XVII), pl. 38, figs. 1, 1*a*.
Echinus ventricosus LAMARCK, *1840*, Histoire naturelle des animaux sans vertèbres, 2me ed., t. 3, p. 358.
Tripneustes ventricosus LÜTKEN, *1864*, Naturh. Forening Kjöbenhavn, vidensk. Meddelelser, 1863, ser. 2, vol. 5, p. 95.
Hipponoë esculenta A. AGASSIZ, *1872*, Harvard College, Mus. Comp. Zool., Mem., vol. 3, no. 4, p. 301, pl. 6a, figs. 1–3; pl. 8, fig. 29.
Tripneustes esculenta H. L. CLARK, *1912*, idem, vol. 34, no. 4, p. 285.

Occurrence.—West Indian region as far north as southern Florida (Agassiz).
Geologic horizon.—Recent.

Genus PHYMOTAXIS Lambert and Thiéry, 1914

Micropeltis POMEL, *1883*, Classification méthodique et genera des échinides vivants et fossiles, p. 89. Not REDTENBACHER, *1867*, nor KRAATZ, *1880*.
Phymotaxis LAMBERT and THIÉRY, *1914*, Essai de nomenclature raisonnée des échinides, fasc. 4, p. 253.

Genotype, *Leiosoma tournoueri* Cotteau (1866, p. 768, pl. 1187), from the Senonian of Roquefort, France, by original designation.

PHYMOTAXIS MANSFIELDI Cooke, n. sp.
Plate 4, figures 6–8

Test large, nearly circular; upper surface somewhat depressed; lower surface evenly rounded, concave near the peristome. Apical system unknown. Ambulacral areas little more than half as wide as interambulacral areas; pores on upper surface and on ambitus arranged in connected arcs, six to eight pairs on each plate; pore pairs crowded on lower surface. Tubercles large, imperforate; two rows on each ambulacral area, four rows on each interambulacral area at the ambitus, the lateral rows dwindling and disappearing away from the ambitus; each primary tubercle surrounded by a line of little tubercles that generally follow the edges of the plates, one little tubercle at each angle of the plates being somewhat larger than the others. Peristome small, subdecagonal; gill slits about as deep as wide, callous.

Maximum and minimum diameters of syntype *a*, 56 and 54 mm.; height, 27.5 mm.; diameter of peristome, 19 mm.

Occurrence.—Three-fourths mile southwest of Brooksville, Fla., (station 12755, from bottom of abandoned quarry of Florida Rock Products Co., W. C. Mansfield and G. M. Ponton, collectors); 3 miles northeast of Brooksville (station 12321, W. C. Mansfield and F. S. MacNeil, collectors).

Geologic horizon.—Late Oligocene, Suwannee limestone, or late Eocene, Ocala limestone.

Syntypes.—U. S. Nat. Mus. 372868.

Remarks.—This species is known only from the three syntypes, two of which are nearly complete and the third is a better-preserved fragment of a smaller individual. All three have lost the genital and ocular plates. The pore pairs below the ambitus, though crowded out of line, are not in two distinct rows like those shown in Cotteau's figure of *Leiosoma tournoueri*. In other respects *Phymosoma mansfieldi* appears to be very similar to the genotype. The quarry in which the syntypes were collected may have cut through the Suwannee limestone into the Ocala.

Family ECHINOMETRIDAE
Genus ECHINOMETRA Gray, 1825

Echinometra GRAY, *1825*, Annals of Philosophy, ser. 2, vol. 10, p. 426.
Ellipsechinus LÜTKEN, *1864*, Naturh. Forening Kjöbenhavn, vidensk. Meddelelser, 1863, ser. 2, vol. 5, p. 165.
Echinometra A. AGASSIZ, *1872*, Harvard College, Mus. Comp. Zool., Mem., vol. 3, p. 282.
Echinometra H. L. CLARK, *1912*, idem, vol. 34, no. 4, p. 370.
Ellipsechinus LAMBERT and THIÉRY, *1914*, Essai de nomenclature raisonnée des échinides, fasc. 4, p. 256.

Genotype, *Echinus lucunter* Linné, living in the Atlantic Ocean, by original implicit designation and direct designation by H. L. Clark.

An earlier use of the name *Echinometra* (Meuschen, 1778) may invalidate the name as here accepted or may change the genotype.

ECHINOMETRA LUCUNTER (Linné)

Echinus lucunter LINNÉ, *1758*, Systema naturae 10th ed., p. 665.

Cidaris subangularis LESKE, *1778*, Additamenta ad Kleinii Echinodermata, p. 106, pl. 3, figs. *C, D.*
Echinometra lucunter LÜTKEN, *1864*, Naturh. Forening Kjöbenhavn, vidensk. Meddelelser, 1863, ser. 2, vol. 5, p. 86.
Ellipsechinus macrostomus LÜTKEN, *1864*, idem, p. 86.
Echinometra subangularis A. AGASSIZ, *1872*, Harvard College, Mus. Comp. Zool., Mem., vol. 3, pt. 2, p. 283, pl. 10a, figs. 2–4.
Echinometra lucunter H. L. CLARK, *1912*, idem, vol. 34, no. 4, p. 372.
Not *Echinometra lucunter* A. AGASSIZ, *1873*, idem, vol. 3, pt. 3, p. 431, pl. 4b, fig. 4; pl. 6f, fig. 12; pl. 36f, fig. 1.

Occurrence.—Living in the Atlantic Ocean and adjacent waters as far north as Florida.
Geologic horizon.—Recent.

Family STRONGYLOCENTROTIDAE

Genus STRONGYLOCENTROTUS Brandt, 1835

Strongylocentrotus BRANDT, *1835*, Acad. imp. Sci. St. Pétersbourg, Recueil des Actes, p. 263.
Stronglyocentrotus A. AGASSIZ, *1872*, Harvard College, Mus. Comp. Zool., Mem., vol. 3, pp. 161, 276.
Strongylocentrotus H. L. CLARK, *1912*, idem, vol. 34, p. 352.

Genotype, *Echinus chlorocentrotus* Brandt, 1835 = *E. dröbachiensis* Müller, 1776. Brandt referred one other species, *Echinus tuberculatus* Blainville, questionably to his subgenus *Strongylocentrotus*. Lambert and Thiéry (1914, p. 242) place *Strongylocentrotus* in the synonymy of *Echinus* Linné, 1758, and refer *E. dröbachiensis* to *Toxocidaris* A. Agassiz, 1863.

STRONGYLOCENTROTUS DRÖBACHIENSIS (Müller)

Echinus dröbachiensis MÜLLER, *1776*, Zoologiae danicae prodomus, p. 235.
Echinus chlorocentrotus BRANDT, *1835*, Acad. imp. Sci. St. Pétersbourg, Recueil des Actes, p. 264.
Strongylocentrotus dröbachiensis A. AGASSIZ, *1872*, Harvard College, Mus. Comp. Zool., Mem., vol. 3, pp. 277, 441, pl. 41, figs. 2, 3, 6; pls. 9, 10.
Strongylocentrotus dröbachiensis H. L. CLARK, *1912*, idem, vol. 34, p. 358.
?Strongylocentrotus dröbachiensis CLARK and TWITCHELL, *1915*, U. S. Geol. Survey, Mon. 54, p. 216, pl. 99, figs. 1a–c.
Strongylocentrotus dröbachiensis GRANT and HERTLEIN, *1938*, California Univ. L. A., Pub. in Math. and Phys. Sci., vol. 2, p. 33.

Occurrence.—Circumpolar; North Atlantic as far south as New Jersey.
Geologic horizon.—Recent. Reported from the Pliocene, Caloosahatchee formation.

Remarks.—Clark and Twitchell report two individuals of this common northern Recent species from the Caloosahatchee formation of Florida. This identification should be accepted with considerable reservation, for the figured specimen is very poorly preserved. The living species is very common off the coast of Maine.

REFERENCES

AGASSIZ, ALEXANDER, *1863*, List of the echinoderms sent to different institutions in exchange for other specimens, with annotations: *Harvard College, Mus. Comp. Zool., Bull.*, vol. 1, no 2, pp. 17–28.
——, *1869*, Preliminary report on the echini and star-fishes dredged in deep water between Cuba and the Florida Reef by L. F. de Pourtales, Assist. U. S. Coast Survey: *idem*, no. 9, pp. 253–308.
——, *1872–1874*, Revision of the echini: *idem, Mem.*, vol. 3, 762 pp., 45 pls.
——, and CLARK, H. L., *1907–1909*, Hawaiian and other Pacific echini; *idem, Mem.*, vol. 34; *1907*, The Cidaridae: no. 1, pp. 1–42, pls. 1–42; *1908*, Salenidae, Arbaciadae, Aspidodiadematidae, and Diadematidae: no. 2, pp. 45–132, pls. 43–59; *1909*, Echinothuridae: no. 3, pp. 137–203, pls. 60–89.
AGASSIZ, LOUIS, *1838*, Des salénies: *Monographies d'échinodermes vivans et fossiles, Mon.* 1, 32 pp. 5 pls.
——, *1840*, *Catalogus systematicus ectyporum echinodermatum fossilium musei Neocomensis*, 20 pp.
——, *1841*, Observations sur les progrès récens de l'histoire naturelle des échinodermes: *Monographies d'échinodermes vivans et fossiles, Introduction*, 20 pp.
——, *1841*, Des scutelles: *idem, Mon.* 2, 152 pp., 21 pls.
——, and DESOR, E., *1846*, *1847*, Catalogue raisonné des familles, des genres et des espèces de la classe des échinodermes: *Annales Sci. nat. (zool.)*, sér. 3, t. 6, pp. 305–374, pls. 15, 16; t. 7, pp. 129–168; t. 8, pp. 5–35, 355–381. (Also reprint, 167 pp., 2 pls. combined, dated 1847.)
ARNOLD, B. W., and CLARK, H. L., *1927*, Jamaican fossil echini: *Harvard College, Mus. Comp. Zool., Mem.*, vol. 50, no. 1, pp. 1–84, pls. 1–22.
——, *1934*, Some additional fossil echini from Jamaica: *idem*, vol. 54, no. 2, pp. 139–156, pls. 1–5.
BRANDT, J. F. VON, *1835*, *Prodromus descriptionis animalium ab H. Mertensio in orbis terrarum circumnavigatione observatorum.*
CLARK, H. L., *1907*, The Cidaridae: *Harvard College, Mus. Comp. Zool., Bull.*, vol. 51, no. 7, pp. 165–230, pls. 1–11.
——, *1912*, Hawaiian and other Pacific echini; the Pedinidae, Phymosomatidae, Stomopneustidae, Echinidae, Temnopleuridae, Strongylocentrotidae, and Echinometridae: *idem, Mem.*, vol. 34, no. 4, pp. 209–383, pls. 90–121.
CLARK, W. B., and TWITCHELL, M. W., *1915*,

The Mesozoic and Cenozoic Echinodermata of the United States: *U. S. Geol. Survey, Mon.* 54, 341 pp., 108 pls.

CONRAD, T. A., *1850*, Descriptions of one new Cretaceous, and seven new Eocene fossils: *Acad. Nat. Sci. Philadelphia, Jour.*, ser. 2, vol. 2, pp. 39–41, pl. 1.

COTTEAU, G., *1861–1867*, Terrain crétacé, Échinides: *Paléontologie française*, sér. 1, t. 7, 892, pp. 1007–1204.

——, *1875–1880*, Terrain jurassique, Échinides reguliers: *idem*, t. 10, pt. 1, 958 pp., pls. 143–520.

——, *1885–1889*, Terrain tertiaire, Échinides éocènes: *idem*, t. 1, 672 pp., pls. 1–200.

——, *1889–1894*, Terrain tertiaire, Échinides éocènes: *idem*, t. 2, 765 pp., pls. 201–384.

COTTEAU, G., PERON, A., and GAUTHIER, V., *1873–1883, Échinides fossiles de l'Algérie.*

DESOR, E., *1855–1858, Synopsis des échinides fossiles*, 490 pp., 44 pls.

DUNCAN, P. M., and SLADEN, W. P., *1882–1886*, Fossil Echinoidea of Western Sind and the coast of Baluchistan and of the Persian Gulf, from the Tertiary formations: *Palaeontologia Indica*, ser. 14, vol. 1, pt. 3, 367 pp., 58 pls.

GRANT, U. S. IV, and HERTLEIN, L. G., *1938*, The West American Cenozoic Echinoidea: *California Univ. L. A., Pub. in Math. and Phys. Sci.*, vol. 2, 225 pp., 30 pls.

GRAY, J. E., *1825*, An attempt to divide the Echinida, or sea eggs, into natural families: *Annals of Philosophy*, ser. 2, vol. 10, pp. 423–431.

JACKSON, R. T., *1922*, Fossil echini of the West Indies: *Carnegie Inst. Washington, Pub.* 306, pp. 1–103, pls. 1–18.

LAMARCK, J. P. B. A. DE, *1816, Histoire naturelle des animaux sans vertèbres*, t. 3; *1840*, 2d ed., t. 3, Les radiaires.

LAMBERT, J., and THIÉRY, P., *1909–1925, Essai de nomenclature raisonnée des échinides*, 605 pp., 15 pls.

LESKE, N. G., *1778, Additamenta ad Kleinii Echinodermata*, in KLEIN, J. T., *Naturalis dispositio echinodermatum*, pp. 65–278, pls. 1–54.

LÜTKEN, CHR., *1864*, Bidrag til Kundskab om Echiniderne: *Naturh. Forening Kjöbenhavn, vidensk. Meddelelser, 1863*, ser. 2, vol. 5, pp. 69–207, pls. 1, 2.

MEUSCHEN, F. C., *1778, Museum Gronovianum.*

POMEL, N. A., *1869, Revue des échinodermes et de leur classification*, 67 pp.

——, *1883, Classification méthodique et genera des échinides vivants et fossiles*, 132 pp.

SLOAN, EARLE, *1908*, Catalogue of the mineral localities of South Carolina: *South Carolina Geol. Survey*, ser. 4, *Bull.* 2.

TUOMEY, MICHAEL, *1848, Report on the geology of South Carolina.*

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THE TRINUCLEIDAE—WITH SPECIAL REFERENCE TO NORTH AMERICAN GENERA AND SPECIES

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ABSTRACT—The thirteen genera, three of which are new, of the Family Trinucleidae are diagnosed or discussed, and grouped into four new subfamilies. Data relating to the stratigraphical position and range of position of each genus in Europe and North America is given. Genera belonging to three, and perhaps the four, subfamilies are known from the Ordovician of Europe and North America, but only two, perhaps three, genera are common to the rocks of the two countries.

One new genus and four new species from Oklahoma, and a new variety from New York, are described. Two previously described species. *Trinucleus acervulosus* and *Tretaspis elevata*, are made the types of new genera, and *Cryptolithus tesselatus*, *C. bellulus*, and *T. reticulatus* are redescribed. Notes on two species from South Manchukuo are added. Some developmental stages of four species are described.

RECENT studies in Europe, especially by Mr. B. B. Bancroft, Dr. L. Størmer, and Dr. C. J. Stubblefield, have led to the discrimination of many new genera and species within the family Trinucleidae, and have greatly increased the stratigraphical value of the group in the Ordovician rocks. In the light of this recent work I have revised most of the genera and species of trinucleids known to me to have been described from North American rocks. In addition, Dr. E. O. Ulrich very generously allowed me to work on collections from Oklahoma, on which he had already placed manuscript names. I have also examined two species from South Manchuria, the types of which were available to me.

While working at the United States National Museum Dr. R. S. Bassler, Dr. C. E. Resser, Dr. C. Butts, Dr. J. Bridge, and Dr. G. A. Cooper afforded me every assistance and made much new material available to me. I am especially grateful to Dr. Cooper, who allowed me the use of his personal camera in making most of the photographs. Through the kindness of Dr. C. A. Adams and Dr. Winifred Goldring I investigated type material in the New York State Museum, and photographs of these types were made for me. At Harvard, Dr. P. E. Raymond allowed me access to the collections in his care, and Dr. F. M. Carpenter made the photographs which form figures 4 and 29 on plate 5. I am indebted to Dr. C. J. Stubblefield, Geological Survey of Great Britain, for photographs of the type of *Marrolithus favus* (Salter). The continued critical interest of Dr. C. O. Dunbar and Dr. Raymond in my work has been a great encouragement to me.

The descriptive terminology adopted in this paper follows that which I used recently to describe some Bohemian trinucleids (Whittington, 1940), with one exception. A pair of pits, situated at the anterior end of the axial furrows, has long been known in many genera of trilobites. The names and supposed functions ascribed to these pits have been various (see Woodward, 1883). They have been regarded as points for the insertion of antennae (McCoy, 1846, p. 42), points of muscle attachment for the hypostome (Salter, 1853, pl. 7, p. 2; Barrande, 1852, p. 230), or possible olfactory organs (Ruedemann, 1916, p. 147). Reed (1914a, p. 351) suggested that these pits be called "pseudo-antennary" pits, and this term has been used recently, as also has "antennuary" pits. It would seem advisable to have a descriptive term for these pits which did not imply or suggest any function, and I, therefore, propose that they be referred to as "anterior" pits. I do not think that the function of these pits can be said to be understood, and I hope to discuss this subject in greater detail in another paper.

It should be emphasized that this work has been almost entirely on collections in museums, I have collected very little material in the field. This is particularly unfor-

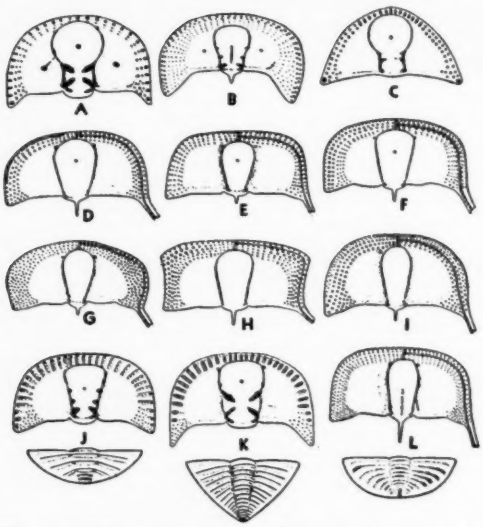


Fig. 1.—Diagrammatic sketches showing some of the characters of 12 genera of the Trinucleidae. A, *Tretaspis*, after Størmer; B, *Reedolithus*, after Reed; C, *Novaspis;* D, *Cryptolithus;* E, *Broeggerolithus;* F, *Onnia;* G, *Cryptolithoides;* H, *Marrolithus;* I, *Salterolithus;* J, *Trinucleus;* K, *Paratrinucleus;* L, *Lloydolithus*. A–C, J, K, showing upper lamella of fringe only; D–I, L, showing upper lamella on left, lower on right.

tunate in regard to the new Oklahoma species. It is possible that future work will show that the Trinucleidae have greater stratigraphical value in the North American Ordovician rocks than present knowledge indicates.

SUBFAMILIES AND GENERA OF THE FAMILY TRINUCLEIDAE

Størmer (1930, pp. 13–15) recognized five genera within the Trinucleidae—*Trinucleus*, *Reedolithus*, *Cryptolithus*, *Tretaspis*, and *Trinucleoides*. I have recently (Whittington, 1940) reinvestigated the type of the genus *Trinucleoides* Raymond, and am of the opinion that it should not be placed with the Trinucleidae, but probably with the Dionideidae. Disagreement has been expressed (see Whittington, 1940) with Størmer's view that three of the genera erected by Bancroft (1929, pp. 76–79) are invalid. Three further new genera were erected by Bancroft in 1933,[1] and I propose three new ones in this paper. Thus the family now includes a total of thirteen genera, and I further suggest that these should be grouped into four subfamilies, which are defined in the following paragraphs, together with diagnoses and discussions of the new genera, and additional restrictive characteristics of earlier genera. Some of the characters of 12 of the genera are shown diagrammatically in figure 1.

[1] A fourth genus, *Ulricholithus*, proposed by Bancroft (1933, p. 2), cannot be regarded as valid.

Subfamily TRINUCLEINAE Whittington, n. subfam.

Trinucleidae having glabellae with more or less prominent pseudofrontal lobe, three pairs of glabellar furrows, the second and third pairs well-marked. Lateral eye tubercles may or may not occur. Fringe with pits in upper lamella deeply sunk in radial sulci anteriorly and laterally.

Genus TRINUCLEUS Murchison, 1839

Genotype, *Trinucleus fimbriatus* Murchison, 1839.

MURCHISON, *1839*, p. 659.
RAYMOND, *1925*, pp. 19–20.
STØRMER, *1930*, p. 14.

I would further restrict the genus to forms in which the glabella narrows posteriorly, and the pygidium is short and broad, in general between three and four times as broad as long.

Genus PARATRINUCLEUS Whittington n. gen.

Genotype, *Trinucleus acervulosus* Raymond, 1920.

RAYMOND, *1925*, pp. 20–21, pl. 1, fig. 18.

Cephalon very similar to *Trinucleus*. Glabella only slightly narrower posteriorly than anteriorly, three pairs of glabellar furrows, the second and third pairs deep, and demarcating the convex pseudofrontal lobe and the large subtriangular lateral lobes. Fringe with pits anteriorly and laterally in deep radial sulci. Thorax with six segments. Pygidium subtriangular in outline, about twice as wide as long, with numerous segments in the axis and pleural lobes.

Discussion: This genus is distinguished by the glabella, which is almost parallel-sided and has the lateral lobes, and by the pygidium. The forms to which I would restrict the genus *Trinucleus* have the glabella narrow-

ing posteriorly, with three pairs of glabellar furrows, the second and third pairs being deep. The cheek lobes show lateral eye tubercles (Størmer, 1930, p. 14, etc.) although Raymond (1925, p. 20) states that they are absent, and they are not shown in Murchison's figure of the genotype (1839, pl. 23, fig. 2). Lateral eye tubercles are not present in the specimen that I have of *T. murchisoni* (pl. 5, fig. 23). The fringe has the pits in radial sulci, and there are intercalated pits externally to the girder in *T. murchisoni* (see also Reed, 1912, pl. 18, fig. 11, pl. 19, fig. 3, 3a). *T. fimbriatus* and *T. murchisoni* have the fringe prolonged posteriorly beyond the rest of the cephalon. The pygidium of *Trinucleus* is very short and broad, e.g., *T. murchisoni* and the Norwegian forms described by Størmer (1930). The proportionally much larger pygidium of *T. fimbriatus* figured by Murchison is said by Salter (1853, pl. 7, p. 8) to belong to *Ampyx nudus*. The genus *Trinucleus* as thus restricted embraces forms having a considerable variety of fringe characters, but with the rest of the cephalon and the thorax and pygidium very similar. The present state of our knowledge does not seem to justify further subdivision of this group.

Subfamily TRETASPINAE Whittington, n. subfam.

Trinucleidae having glabellae with prominent pseudofrontal lobe, sometimes carinate posteriorly, three pairs of glabellar furrows, the second and third pairs well-developed. Lateral eye tubercles and eye lists prominent. Fringe divided into convex cheek roll and concave brim, on the upper lamella the former frequently with concentric lists between rows, the latter often with pits in radial sulci anteriorly.

Genus TRETASPIS McCoy, 1849

Genotype, *Asaphus seticornis* Hisinger.

McCOY, *1849*, pp. 410–411.
RAYMOND, *1925*, p. 19.
STØRMER, *1930*, p. 15.

The forms included in this genus have two rows of pits external to the girder, sometimes fusing anteriorly and anterolaterally into one row (e.g., *T. cerioides*, *T. seticornis*).

Genus REEDOLITHUS Bancroft, 1929

Genotype, *Trinucleus subradiatus* Reed, 1903.

REED, *1903*, pp. 12–14, pl. 2, figs. 1–6.
BANCROFT, *1929*, pp. 77–78.
STØRMER, *1930*, p. 14.

The relationships of this genus have been discussed by Størmer (1930, pp. 39, 82–83). The adult *Reedolithus* resembles *Tretaspis* in having three pairs of glabellar furrows, lateral eye tubercles and eye lists, and in the inclination and shape of the fringe. It differs from *Tretaspis* in that the pseudofrontal glabellar lobe is not well-developed, and there is only one row of pits external to the girder, and it possesses an occipital spine.

In seeking relationships of subfamily rank I would place emphasis on the former of these characters and associate *Reedolithus* and *Tretaspis*, regarding *Reedolithus* as probably the earlier genus and a possible ancestral form.

Subfamily CRYPTOLITHINAE Bancroft, 1933, emend.

Trinucleidae with glabellae clavate, sometimes carinate, one pair of extremely short glabellar furrows. Cheek lobes without lateral eye tubercles or eye lists. Fringe flat, more or less inclined ventrally.

The name Cryptolithinae has been used by Bancroft (1933, p. 2; in Lamont, 1935, p. 333) without precise definition, but it would seem that he regarded the subfamily as including the genera *Cryptolithus*, *Broeggerolithus*, *Marrolithus*, *Reuscholithus* and *Salterolithus*. To these I would add *Onnia* and *Cryptolithoides*, n. gen., and for the present *Lloydolithus* should perhaps be placed here.

Genus CRYPTOLITHUS Green, 1832

Genotype, *Cryptolithus tesselatus* Green, 1832.

GREEN, *1832*, pp. 72–78.

Cephalon quite strongly arched. Glabella clavate, sometimes carinate, one pair of very small glabellar furrows. Cheek lobes without lateral eye tubercles. Fringe often quite steeply inclined, with rather large pits, one row external to the girder. Upper lamella with pits in strong concentric arrangement, often with concentric ridge between rows;

usually radial arrangement anteriorly, raised radial plates in the external row or rows characteristic. Genal spines directed backwards or flexed slightly outwards.

Thorax with six segments. Pygidium triangular in outline.

Genus BROEGGEROLITHUS Stubblefield, 1935

Genotype, *Cryptolithus broeggeri* Bancroft, 1929.

BANCROFT, *1929*, pp. 85–86, pl. 1, figs. 6–8.
BANCROFT, *1933*, p. 2, *Broeggeria* preoccupied.
STUBBLEFIELD, in LAMONT, *1935*, p. 320, footnote.

Genus CRYPTOLITHOIDES Whittington, n. gen.

Genotype, *Cryptolithoides ulrichi* Whittington, n. gen., n. sp.

Glabella clavate, one pair glabellar furrows. Cheek lobes without lateral eye tubercles. Reticulate ornament absent. Occipital spine present. Fringe with numerous small pits, one row external to girder. I_1 in concentric and radial arrangement with E_1; internally to I_1 arrangement radial anteriorly, irregular and with additional pits laterally, producing anterolateral angulation of the cephalic margin. Genal spines flexed strongly outwards.

Thorax with six segments. Pygidium triangular in outline.

Discussion: The characters of the glabella and cheek lobes place this genus in the Cryptolithinae, despite the absence of reticulate ornament. The fringe resembles that of *Marrolithus* in having one row of pits external to the girder, the anterolateral angulation of the cephalic margin, and the direction of the genal spines. The disposition of the pits within the girder in these two genera is quite different.

Genus LLOYDOLITHUS Bancroft, 1933

Genotype, *Trinucleus lloydi* Murchison, 1839.

MURCHISON, *1839*, p. 660, pl. 23, fig. 4.
SALTER, *1853*, pl. 7, pp. 1–4.
BANCROFT, *1933*, pp. 2–3.

Bancroft characterized the genus as having "an unique type of pygidium." The genotype is figured and described by Salter, and I illustrate specimens in the U. S. National Museum (pl. 6, figs. 24, 28). The characters are:

Glabella clavate, ?carinate posteriorly, one pair of glabellar furrows, lateral to which are small convex alae. Occipital spine present. No lateral eye tubercles. Fringe with two rows external to girder, strong concentric and anteriorly, radial, arrangement of pits; posterolaterally they form an irregular network. Genal spines flexed slightly outwards. Thorax of six segments. Pygidium depressed semicircular in outline, the ribs demarcating the pleurae sharply bent posteriorly at their extremities.

The presence of alae and the possibly carinate glabella are features which in other genera of the Cryptolithinae are only seen in the young stages. Though the characters of the glabella and cheek lobes and the presence of an occipital spine lead me to place this genus in the Cryptolithinae, the fringe of the genotype has features in common with *Tretaspis* in having two rows external to the girder, and a wide internal region anteriorly and laterally with four rows of pits, E_1, I_1 and I_2 being separated by concentric lists. The pygidium is quite unlike that of any other genus within the family.

Genus MARROLITHUS Bancroft, 1929

Genotype *Trinucleus ornatus* var. *δ favus* Salter, 1848.

SALTER, *1848*, p. 350, pl. 9, fig. 3.
BANCROFT, *1929*, p. 77.
STUBBLEFIELD, *1938*, p. 36.

Glabella clavate, ? one pair of small glabellar furrows. Occipital spine present. No lateral eye tubercles. Fringe with one row of pits external to the girder. In upper lamella, pits in concentric arrangement, except anteriorly, where, within E_1, the pits are in shallow radial sulci separated in front of the glabella by rather wide radial ridges. Anterolaterally the internal rows divide and reunite and frequently are raised in a honeycomblike structure (see pl. 6, fig. 19), with consequent anterolateral angulation of the cephalic margin. Genal spines flexed strongly outwards.

Thorax of six segments. Pygidium triangular in outline.

Genus ONNIA Bancroft, 1933

Genotype, *Cryptolithus superbus* Bancroft, 1929.

BANCROFT, *1929*, pp. 95–96, pl. 2, fig. 10.
BANCROFT, *1933*, p. 2.
WHITTINGTON, *1940*.

Genus REUSCHOLITHUS Bancroft, 1929

Genotype, *Reuscholithus reuschi* Bancroft, 1929.

BANCROFT, *1929*, p. 78, pl. 1, figs. 3–5.

The fringe is "characterized by the small region external to the girder and the wide internal region, the irregular character and disposition of the pits, and the ill-defined girder." The genal spines arise "somewhat in advance of the posterior margin of the fringe."

No specimens referable to this genus have been available to me for study.

Genus SALTEROLITHUS Bancroft, 1929

Genotype, *Trinucleus caractaci* Murchison, 1839.

MURCHISON, *1839*, p. 659, pl. 23, figs. 1a–f.
BANCROFT, *1929*, p. 78.

The characters of the genotype species are indicated in text fig. 1*i*, The presence of three, sometimes four, rows outside the girder is characteristic of the genus, and the outer of these rows fails at the genal angles, where E_1 is external. On the upper lamella of *Salterolithus caractaci* concentric lists separate E_2 and E_1, E_1 and I_1, and I_1 and I_2.

Subfamily NOVASPINAE
Whittington, n. subfam.

Trinucleidae having glabellae with very prominent, strongly convex pseudofrontal lobe, narrower, depressed posterior portion, glabellar furrows indistinct. Fringe flat, narrow.

Genus NOVASPIS Whittington, n. gen.

Genotype, *Tretaspis elevata* Cooper and Kindle, 1936.

COOPER and KINDLE, *1936*, pp. 361–362, pl. 52, figs. 19, 25, 28.

Glabella with very strongly elevated pseudofrontal lobe, posterior portion low, parallel-sided, two pairs of short, very shallow glabellar furrows. No occipital spine. Cheek lobes smooth, without lateral eye tubercles. Fringe narrow, flat, gently inclined ventrally, lower lamella unknown.

Thorax and pygidium unknown.

Discussion: The distinctive glabella and the narrow fringe with two rows of large pits distinguish the new genus from all the other genera of the family, and the relationships of this form seem obscure.

STRATIGRAPHICAL OCCURRENCE AND DISTRIBUTION OF THE TRINCULEIDAE

The table is an attempt to summarize the stratigraphical position or range of position of the genera of the Trinucleidae in Europe and North America, from present knowledge of the family. Only the most general intercontinental correlation is intended. The sources are, in the main, Bancroft (1929, 1933), Størmer (1930), Lamont (1935), Stubblefield (1939), and Elles (1937), in combination with this present study. There are many interresting features in the distribution of the genera within each subfamily.

TRETASPINAE

Reedolithus occurs in the Balclatchie group, Girvan, Scotland (Reed, 1903, pp. 12–14), and in the Ampyx limestone of Scandinavia (Størmer, p. 33, 75), rocks of high Llandeilo or low Caradoc age (Elles, tables). Bancroft (1929, table) regards the Girvan *Reedolithus* as older than *Marrolithus*, which is typical of the Llandeilo.

Tretaspis seems to make its first appearance in Europe in the Raheen shales of County Waterford, Ireland, rocks of probably low Caradoc age (Stubblefield, p. 59, footnote). The genus is well represented in the Ashgillian of Wales, Scotland and Scandinavia. In the United States *Tretaspis* is first known from the Chambersburg of Virginia, and from the Rysedorph conglomerate of New York. The former strata may be as old as the Raheen shales. The *Tretaspis* from the Gaspé peninsula, Quebec, occurs in a fauna which has remarkable affinities with the Ashgillian of Europe (Cooper and Kindle, 1936, p. 349).

CRYPTOLITHINAE

Lloydolithus is known only from the Llanvirn and Llandeilo rock of Wales and Shrop-

shire, Great Britain, (Salter, pl. 7, p. 4). It is not possible to determine to what genera the forms recently described by Elles (1939, pp. 423–438, pls. 29–31) should be referred. "*Trinucleus*" *chamberlaini* and "*Trinucleus* (*Cryptolithus*)" *gibbosus* occur in lower Llanvirn rocks, and do not seem to belong either to the genus *Trinucleus* or to *Cryptolithus*, but may be species of *Lloydolithus*. In higher rocks, of Llandeilo age, Elles records *Lloydolithus lloydi* (1939, p. 412) and describes a new form, *Trinucleoides reticulatus*. This latter cannot, from the description, belong to *Trinucleoides*, and may also be a species of *Lloydolithus*.

The stratigraphical distribution of the genera *Marrolithus*, *Salterolithus*, *Broeggerolithus* and *Onnia* has been discussed by Stubblefield (pp. 54–57). The age of *Reuscholithus* is indicated by Bancroft (1929, table). All these genera, except perhaps *Salterolithus*, are known in Europe outside the Anglo-Welsh area but are unknown on the American continent.

Cryptolithus makes its appearance in New York, Ontario, Quebec, Pennsylvania, and Virginia in rocks of lower Trenton age, and is found in New York, Pennsylvania, Ohio and Kentucky in rocks of Eden and Maysville age. The occurrence of *Cryptolithus* and the new genus *Cryptolithoides* in Oklahoma is approximately contemporaneous with that of the Trenton forms in the East.

Cryptolithus is known from the Killey Bridge beds, Pomeroy, Ireland. These beds have been regarded as Ashgillian in age, but uncertainty as to this view has recently been expressed by Stubblefield (p. 60). The genus is also known from the Drummuck group, Girvan, Scotland (Lamont, pp. 317–321). Present knowledge does not seem to allow of any opinion as to where *Cryptolithus* makes its earliest appearance.

Trinucleinae

Trinucleus occurs in the Arenig and Llanvirn of the Anglo-Welsh area (Stubblefield, pp. 53–54). The species in the Tramore limestone (Reed, 1895) seems to be of about Llandeilo age (Stubblefield, p. 58), and the forms described by Elles (1939, pp. 424–425, pl. 30) as *Trinucleus fimbriatus*, *T. fimbriatus* mut. *primus*, and *T. fimbriatus* mut. *ultimus* are of Llandeilo and low Caradoc age. The Scandinavian forms in the Ampyx limestone are of approximately the same age (Størmer, pp. 74–75; Elles, 1937, tables).

Paratrinucleus occurs in the Athens shale of Virginia, and is thus about high Chazy age, which may be approximately high Llandeilo or low Caradoc.

Novaspinae

Novaspis occurs contemporaneously with *Tretaspis* in the Whitehead formation of the Gaspé peninsula, Quebec. If I am correct in suggesting (see below) that "*Trinucleus*" *albidus* belongs with this genus, then it occurs at Girvan, Scotland, in rocks of low Ashgillian or high Caradocian age (Lamont, p. 290; Elles, tables).

The foregoing shows that genera belonging to three, and probably the four, subfamilies of the Trinucleidae are present on both sides of the Atlantic. Two, perhaps three, genera only are common to the Ordovician rocks of Europe and North America, and while ten, perhaps eleven, different genera are known in Europe, five are known in North America.

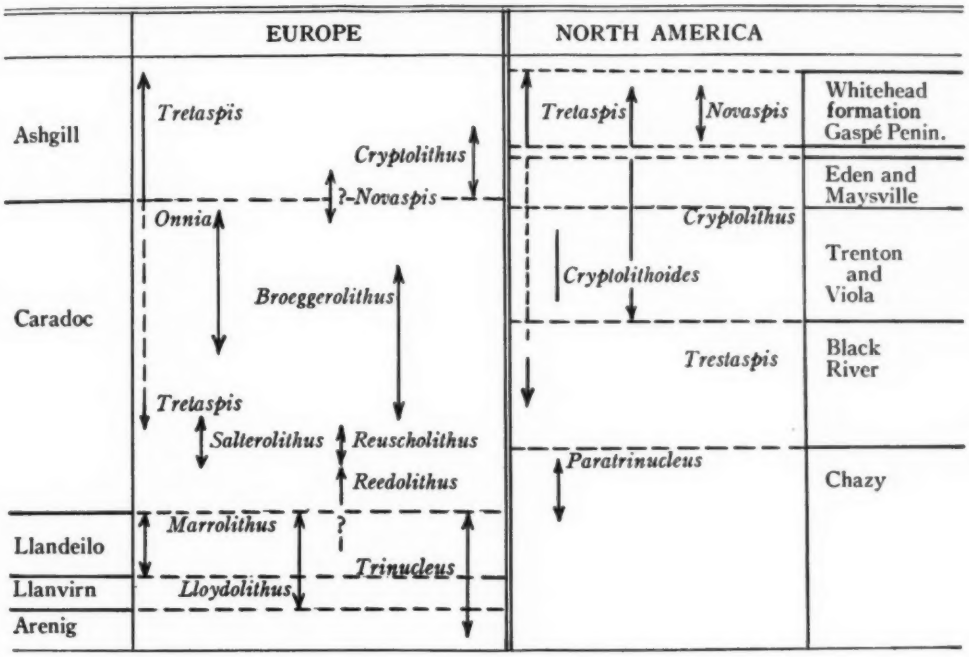
Little that is definite is known of the descent and migration of genera in the Trinucleidae. Bancroft (appendix in Lamont, 1935) has discussed the descent of genera in the Cryptolithinae. It would seem that *Onnia* occurs earliest in the Bohemian area (Whittington, 1940). *Cryptolithus* is very widely distributed in North America and is associated with *Cryptolithoides*, and this suggests the possibility that these genera originate on this side of the Atlantic.

If *Reedolithus* and *Tretaspis* are related, the former would seem to be the earlier genus. The apparently long range of *Tretaspis* is notable.

The relationship, if such there is, between *Trinucleus* and *Paratrinucleus*, is obscure.

Other species, as yet little known, occur in widely scattered parts of the world. From South America "*Trinucleus*" *boliviensis* Lake (1906, pp. 427–428, pl. 40, figs. 4, 5; Kobayashi, 1937, pp. 493–494, pl. 3, fig. 1), *T. krugeri* Hoeck (1912; Kobayashi, 1937, p. 494, pl. 5, figs. 13–14), "*T.*" *nordenskioldi* Bulman (1931, pp. 85–87, pl. 11, figs. 2, 3), and "*Cryptolithus*" *terryi* Leith (1938, pp. 341–342, pl., fig. 2) have been described. The latter two almost certainly represent new

RANGE OF THE TRINUCLEIDAE



genera (the single known specimen of "*C.*" *terryi* is insufficient as a basis for a new genus), as also may "*Cryptolithus*" *primitivus* Born (1921, pp. 191–192) from France. It is clear, therefore, that questions of migration and interrelationships of genera within the Trinucleidae await discovery and description of new material.

PARALLEL TRENDS IN THE TRINUCLEIDAE

There are some examples of parallel trends at different times in different stocks of the Trinucleidae. Considering the pits in the fringe external to the girder in *Trinucleus* (Størmer, 1930, p. 29; Reed, 1912, pl. 19) at least two different types may be seen:

One concentric row, e.g., *T. faveolatus*, *T. bronni*, *T. fimbriatus*. This is paralleled in the Cryptolithinae by *Cryptolithus*.

Two concentric rows, e.g., *T. hibernicus* and variety, *T. bucculentus*. *T. hibernicus* Reed shows a few pits of E_2 missing at the genal angle. This structure may be compared with that of *Broeggerolithus*.

Another fringe structure which occurs at different times is that seen in *Boeggerolithus soudleyensis* (Bancroft, 1929, pp. 86–88). The two rows external to the girder fuse into one anteriorly. This happens to a greater extent in *Tretaspis cerioides* and *T. seticornis* (Størmer, 1930, pp. 47–56).

In part because of this repetition in fringe structures in different stocks I have preferred to base relations of subfamily rank on the structure of the glabella and cheek lobes.

SYSTEMATIC DESCRIPTIONS

Genus PARATRINUCLEUS Whittington, n. gen.

PARATRINUCLEUS ACERVULOSUS (Raymond)

Plate 5, figures 4, 29, 27

Trinucleus acervulosus RAYMOND, *1920*, p. 273; *1925*, pp. 20–21, pl. 1, fig. 18.

A few points may be added to Raymond's description. Glabella almost as wide posteriorly as anteriorly, and the second and third glabellar furrows isolating the rather large, convex, subtriangular lateral lobes. The occipital furrow with elongate lateral depressions, connected by shallow furrows with the third glabellar furrows. I could detect no trace of lateral eye tubercles or

genal caeca. Axial furrows with shallow anterior pits.

The fringe with upper lamella showing three or four rows of pits in deep radial furrows; in front of, and just laterally to, the glabella, one or two pits frequently intercalated marginally in the raised ridges between the furrows. Posteriorly the fringe is prolonged beyond the rest of the cephalon, posterior margin with eight to ten pits. Lower lamella flexed strongly at the broad girder which shows terrace lines. Outside the girder two rows of pits in radial sulci. The girder turns outward at the posterior margin and is continuous with the genal spine.

Thorax with deep appendifers. The line separating the anterior and posterior pleural bands is sharply raised (cf. Størmer, 1930, p. 14).

Genus TRETASPIS McCoy, 1849

TRETASPIS RETICULATUS Ruedemann

Plate 6, figures 26, 27, 30–32, 34, 35

Tretaspis reticulatus RUEDEMANN, *1901*, pp. 41–46, pl. 3, figs. 11, 15–20.

Tretaspis diademata RUEDEMANN, *1901*, pp. 46–48, pl. 2, figs. 12–14.

Two species of *Tretaspis* were described by Ruedemann from the Rysedorph conglomerate. The specimens on which *T. reticulatus* is based represent the cephalon with the external cast of the upper lamella of the fringe. The material on which *T. diademata* is based, said by Ruedemann (1901, p. 46) to have the fringe "present only as an internal cast," show the cephalon with the cast of the ventral surface of the lower lamella of the fringe. I, therefore, regard the material as representing one species, and select the first specific name. The following notes may be added to Ruedemann's description:

Glabella with well-developed pseudofrontal lobe, strongly convex; posterior portion descending steeply to the occipital furrow, weakly carinate. Median tubercle distinct. First pair of glabellar furrows very faint, shallow circular depressions situated immediately posterior to the greatest width of the pseudofrontal lobe. Second pair suboval in outline, shallow, situated at the posterolateral edges of the pseudofrontal lobe. Third pair shallow, commencing immediately anterior to the lateral pits, with which they are connected by shallow furrows, and extending anteromedially. Frontal slope and median area of the glabella with coarse reticulate ornament. Occipital furrow straight, with elongate lateral depressions. Occipital ring elevated, outline of posterior edge curved, without occipital spine. Anterior pits not observed. Cheek lobes with more coarsely reticulate ornament than that on the glabella.

Fringe steeply inclined, divided into a faintly convex cheek roll and a narrow concave brim, prolonged posteriorly beyond the rest of the cephalon. Upper lamella with three rows of pits on the concave brim, in radial sulci anteriorly, becoming three distinct rows laterally. Cheek roll with four rows anteriorly, anterolaterally a new row appears between the two outer rows, and posterolaterally many pits are intercalated, forming an irregular network. Three very prominent concentric lists anteriorly and laterally, situated outside, between, and within the outer two rows of the cheek roll. Anteriorly the pits of the brim and cheek roll are in radial arrangement, this arrangement being lost anterolaterally. Lower lamella (see pl. 2, figs. 30, 31, 35), interiorly to the girder, with five rows of pits, anteriorly in deep radial sulci, laterally and posteriorly the pits are irregularly arranged. Girder strong, two rows of pits externally, the first internal row corresponding to the third, and innermost, row of the concave brim of the upper lamella.

Størmer (1930, pp. 33, 75, 82) thought that *Tretaspis reticulatus* should probably be referred to *Reedolithus*, but I cannot agree with this opinion. The Rysedorph species has the fringe divided into a convex cheek roll and a concave brim, two rows of pits outside the girder, a glabella with well-developed pseudofrontal lobe, and no occipital spine. All these features differentiate it from *Reedolithus*, and are characteristic of *Tretaspis*. The species thus represents an early occurrence of the genus. The glabella, with the carinate posterior portion and the rather shallow glabellar furrows, is very similar to that of the Meraspid degree of later species.

The arrangement of the pits in the fringe and the characters of the upper lamella of *Tretaspis reticulata* are remarkably similar to *T. kiaeri* Størmer (1930, pp. 50–55, pl.

10), especially the specimens shown on pl. 10, figs. 1b and 3a.

A tretaspid occurs in material from two localities in Virginia, and I regard this form as conspecific with *Tretaspis reticulata* (see pl. 2, figs. 30, 32, 34, 35).

TRETASPIS CERIOIDES (Angelin)
Plate 6, figure 36

Tretaspis clarkei COOPER, in SCHUCHERT and COOPER *1930*, pp. 365–368, pl. 4, figs. 1–10.

I have examined the types and other material of *Tretaspis clarkei* Cooper, and in my opinion this species is identical with *T. cerioides* as redescribed by Størmer (1930, pp. 44–48, pl. 9, figs. 1–4).

Larval stages of the cephalon of *Tretaspis cerioides* were found by Størmer, who also described in detail the ontogeny of *T. seticornis*. The Percé material contains a number of small cephala, and they show a development that is very similar indeed to that of *T. seticornis*. The glabella is in the early stages without the pseudofrontal lobe, carinate, very shallow second and third glabellar furrows, and with the narrow, crescentic alae. The lateral eye tubercles and eye lists are prominent, with a marked depression in the axial furrow at the posterior edge of the lists. The glabella develops the adult characters very rapidly, and at the same time the eye lists become less prominent and are faint in the adult.

Genus CRYPTOLITHUS Green, 1832
CRYPTOLITHUS TESSELATUS Green
Plate 5, figures 2, 15, 17, 18

Cryptolithus tesselatus GREEN, *1832*, pp. 73–78, fig. 4.

Ruedemann (1926, pp. 107–111) discusses the differences between the *Cryptolithus* typical of the Trenton and that typical of the Lorraine, and concludes that the former, among other features, is characterized by having three rows of pits anteriorly. This accords well with Green's description—"rounded punctures, in three concentric rows in front." Green's specimens came, apparently, from the Snake Hill beds at Waterford, N. Y., and it would appear from Ruedemann's work and the recent revision by Kay (1937, pp. 263–277, pl. 10) that this is the form typical of the Trenton beds of Sherman Fall age.

The literature on *Cryptolithus tesselatus* is vast, but ever since Green's time there has been confusion as to the exact characters of this species, and I can find no adequate illustration or description. I, therefore, give the following description, based on material in the United States National Museum which I refer to this species:

Cephalon subsemicircular in outline, a little more than twice as wide as long, quite strongly arched. Glabella clavate, strongly convex, standing high above the cheek lobes. One pair of glabellar furrows represented by shallow pits situated immediately anterior to the extremities of the occipital furrow. Median tubercle prominent, median area and frontal slope with reticulate ornament. Occipital furrow shallow, straight, suboval lateral pits. Occipital ring elevated, prolonged posteriorly into the occipital spine. Cheek lobes about as broad as long, rounded posterolateral margins, evenly inflated, descending in an even convex curve from the axial margin to the fringe; steeply inclined posteriorly. Posterior marginal furrow shallow, posterior margin elevated, widening laterally to form a support to the fringe.

Fringe gently inclined, most steeply anteriorly, widening laterally, prolonged posteriorly a little beyond the rest of the cephalon, and with comparatively large pits. One row external to the girder. Upper lamella with three continuous rows of pits, E_1, I_1, and I_2, in concentric arrangement, with radial arrangement anteriorly and anterolaterally, with rather wide raised radial ridges in front of the glabella; I_3 arising at the sixth or seventh pit of I_2 from the axial furrow, I_4 present at the posterolateral margin of the cheek lobes. One or two additional pits at the posterior margin, where the pits form an irregular network. E_1 with strong raised radial plates between the pits, except anteriorly to the glabella. A strong concentric ridge between I_1 and I_2, except anteriorly to the glabella and at the posterior margin. The number of pits in the fringe varies as follows: E_1 with 22–24 pits, I_1 with 21–23, I_2 with 19–23. Lower lamella with very strong girder, with terrace lines. Except posteriorly flexed at the girder, most strongly anteriorly, where the cross section forms a V shape. A strong concentric ridge

between I_1 and I_2. Anteriorly to the glabella, very narrow internally, for about four pits I_1 and I_2 in deep radial sulci. Genal spines long, flexed outwards, channel with terrace lines and continuous with girder.

Thorax of six segments. Axial rings convex, appendifers deep. Axial furrows shallow. Pleurae bent down at the extremities, pleural furrows deep, widening laterally.

Pygidium subtriangular in outline, a little more than twice as wide as long. Rachis convex, narrowing posteriorly, first three or four segments distinct, up to a further 12 indicated. Pleural lobes flat, first segment distinct, a further four indicated. Margin steep, with terrace lines.

Type.—Green's plaster casts cannot be considered a satisfactory basis for the species. Professor B. F. Howell, Acting Curator, Department of Geology and Paleontology, Academy of Natural Sciences, Philadelphia, informs me that Green's original types, from which the plaster casts were made, have probably all been permanently lost. A lectotype should therefore be selected, the type locality being near Waterford, New York. Until such a lectotype is selected, the species *Cryptolithus tesselatus* cannot be regarded as securely founded, although the form described above is very distinctive and characteristic of certain rocks, and would seem, for the reason given above, to be that described by Green.

Horizon and localities.—Typical of the Sherman Fall formation of the Trenton limestone of New York and Vermont—see material from many localities at the U. S. National Museum, Museum of Comparative Zoology, Harvard University, New York State Museum, etc. Trenton near Bellefonte, Pa., and in the lower part of the Salona formation, at Salona, Clinton County, Pa. Top of the Chambersburg, 0.8 mi. northwest of Linville Railroad station, Rockingham County, Va., and Chambersburg near Strasburg, Va.

CRYPTOLITHUS TESSELATUS var. QUADRILINEUS Whittington, n. var.
Plate 6, figures 38, 40

Certain material in collections in the United States National Museum from the Trenton at Trenton Falls and near Poland Bridge, Russia, N. Y., contains, besides normal *Cryptolithus tesselatus*, a number of specimens which are similar in all respects, except for an extra row of pits anteriorly. The arrangement of the pits in the upper lamella of the fringe is:

E_1 with pits separated by raised radial plates, about 23 on each side. I_1 of pits of similar size, without raised radial plates, somewhat depressed, about 22 on each side. I_2 with about 21 pits on each side, very strong concentric ridge between I_1 and I_2 which persists to within one or two pits of the posterior margin. I_3 with usually one to five, one specimen shows nine, pits missing in front of the glabella. Pits a little smaller than I_2. I_4 arising usually at the seventh pit if I_3 from the axial furrow. I_5 present at the posterolateral margins of the cheek lobes. A few additional pits at the posterior margin.

The variety is based entirely on this extra row anteriorly, I_3, and may or may not be of significance stratigraphically. It approaches *C. bellulus* but differs in having rather fewer pits in each row, in possessing the strong raised radial plates in E_1, and the conspicuous concentric ridge between I_1 and I_2, which latter are characteristic of *C. tesselatus* and are not seen in *C. bellulus*. In the latter I_5 extends somewhat farther forward than in *C. tesselatus* var. *quadrilineus*, n. var.

Material that I have examined in collections in the United States National Museum and at Harvard from the Swatara Gap, Lebanon County, Pa., contain a form which seems to be *C. tesselatus* var. *quadrilineus*, n. var. (see plate 6, fig. 40). However, other specimens in the collections may be referred to *C. bellulus*, which species occurs in New York at an horizon considerably above that containing *C. tesselatus*.

Holotype.—U. S. Nat. Mus., from Rathbone Brook, 2 miles below Poland, N. Y.

CRYPTOLITHUS BELLULUS (Ulrich)
Plate 5, figures 1, 7–9, 13, 14, 19, 21, 22, 25, 26, 28

Trinucleus bellulus ULRICH, *1878*, pp. 99–100, pl. 4, fig. 15.
Cryptolithus recurvus ULRICH, BASSLER, *1919*, pp. 334–335, pl. 56, figs. 14–17.
Cryptolithus lorrainensis RUEDEMANN, *1926*, pp. 107–115, pl. 21, figs. 4–5.

The holotype may be redescribed in the following terms:

Cephalon subsemicircular in outline, a lit-

tle more than twice as wide as long. Glabella clavate, quite strongly arched, standing well above the cheek lobes. Somewhat damaged, but probably with reticulate ornament medially. One pair of glabellar furrows, represented by circular depressions situated very close to the axial furrow and immediately in front of the occipital furrow. Occipital furrow broad, shallow, opening out in front of the occipital spine; lateral pits shallow, distinct, subcircular. Occipital ring curving back behind the glabella, and drawn out into a long, stout, horizontal occipital spine, which, despite being broken, reaches back to the anterior edge of the pygidium. The spine is ornamented with tubercles. Axial furrows distinct, shallow, with deep anterior pits, anteriorly to which the glabella encroaches on to the fringe. Cheek lobes about as long as broad, rounded posterolateral margin, evenly inflated, descending steeply to the posterior marginal furrow. Reticulate ornament present. Posterior marginal furrow deep, widening laterally, and opening onto the fringe. Posterior margin elevated, widening and curving slightly backwards to form a support to the fringe.

Fringe flat, narrow and almost horizontal in front of the glabella, widening rapidly and inclined gently downwards anterolaterally and laterally. Posterior edge of fringe in line with posterior border of cephalon. Upper lamella showing the following arrangement of pits:

E_1 marginal, continuous, 24 pits on each side, separated by raised radial plates. I_1 continuous, pits of about the same size as E_1, 23 pits on each side. Anteriorly in radial arrangement with the pits of E_1, and the raised plates tend to extend and separate the pits of I_1 in this region. I_2 continuous, 22 pits on each side. Concentric ridge separates I_1 and I_2, disappearing in the posterolateral portion of the fringe. I_3 continuous, with the exception of one pit in front of the glabella, which unites with I_2. Pits somewhat smaller than I_2. I_4 of small pits, arising by division of pits in radial sulci from I_3 at the seventh pit from the axial furrow. I_5 of small pits, arising from I_4 at the second or third pit. A few additional pits at the posterolateral edge of the cheek lobes. The arrangement of the pits is dominantly in concentric rows. In front of the glabella a strong radial arrangement also exists in E_1 and I_1–I_3, with radial ridges between the pits. This radial arrangement persists in E_1 and I_1 laterally for about six or seven pits, and is then lost. Near the posterior margin of the fringe the concentric arrangement of pits is lost, and an irregular network of somewhat enlarged pits is formed. Lower lamella and consequently the genal spines not present.

Thorax of six segments, not very well preserved. Axial rings moderately convex, axial furrows shallow. Pleural furrows shallow, widening laterally.

Pygidium subtriangular in outline. Rachis forming with the elevated axial regions of the pleural lobes a subtriangular convex area, first segment distinct, the second faint. Axial furrows indistinct. Pleural lobes flat laterally, pleural furrows of first segment distinct, two other segments faintly indicated. Margin an elevated convex ridge with prominent terrace lines.

In my opinion the holotype selected by Ulrich is not a fully grown holaspid shield, and he comments on the small size (1878, p. 100), Bassler (1919, p. 334) refers to it as a young specimen, and the pygidium, with its centrally convex area described above, resembles the transitory pygidium of the meraspid cryptolithid. Among the paratypes is an adult cephalon (pl. 5, fig. 28), and I cannot distinguish this specimen from the cryptolithids of the Fulton shale and the limestones of Cincinnati, Ohio, the Point Pleasant limestone of Kentucky, or the Lorraine shales of New York. Accordingly, I have placed *C. lorrainensis* in the synonomy of *C. bellulus*, and I figure material from the Lorraine of New York, including Ruedemann's types, and the Ohio limestones (pl. 5, figs. 14, 19, 21, 22, 26). From this material I will add further to the specific description:

Characteristic of the upper lamella of the fringe are the alternate pits of E_1 and I_1 anterolaterally, and the absence of concentric ridges between rows. Lower lamella with very prominent girder between E_1 and I_1, showing terrace lines. Lamella bent up somewhat interiorly to the girder. Strong concentric arrangement of I_1–I_4, with concentric ridge, low compared to girder, between I_1 and I_2. Strong raised ridge, which borders the lower lamella anteriorly, and shows terrace lines. Laterally I_5 appears interiorly to

this ridge. Anterior to glabella pits of I_1–I_3 in radial sulci, I_2 and I_3 united for three pits. Variation in the number of pits in each row shown by material assigned to this species is E_1 with 24–29 pits; I_1, 22–27; I_2, 22–26.

Pygidium about three times as wide as long. Rachis moderately convex, decreasing in width posteriorly, first segment distinct, with shallow appendifers, up to nine further segments faintly indicated. Axial furrows distinct, shallow. Pleural lobes flat, five pleurae indicated by the rib furrows, the first, and sometimes the second to the fourth, showing a shallow pleural furrow. Margin of the pleural lobes a convex ridge with terrace lines, and margin of pygidium vertical laterally, less steep posteriorly, with terrace lines.

The species *Cryptolithus recurvus* Ulrich (Bassler, 1919, pp. 334–335, pl. 56, figs. 14–17; Foerste, 1924, pp. 238–239, pl. 45, figs. 12a, b, pl. 43, fig. 18) is distinguished by the posterior recurving of the cephalic margin and the finely punctate ornamentation of the glabella and cheek lobes. The type specimen is incomplete, and I believe distorted in preservation, and thus appears to have the recurved margin. The reticulate ornamentation of the glabella and cheek lobes of the Cryptolithinae may be preserved in strong relief or not at all, with every gradation between these, according to the degree and manner of preservation of the dorsal shield. One of the stages of preservation is that in which the surface of the test appears to be finely punctate, and I believe that Ulrich's type of *C. recurvus* exhibits this condition. I do not, therefore, regard this as a valid distinguishing character, and place this species in the synonomy of *C. bellulus*.

The dimensions are as follows:

	Holotype	Paratype	Pl. 5, fig. 21	Pl. 5, fig. 19
Length of cephalon	3.25	7.55	7.3	6.9
Width of cephalon	7.50	17.1	15.5	15.0
Length of thorax	1.5		3.2	
Length of thorax	.8		10.4	
Length of pygidium	4.6		2.7	
Width of pygidium	3.9		8.8	

Types.—U. S. Nat. Mus. 41876, Eden (Economy bed) Covington, Ky.

Horizon and localities.—Pulaski beds, Lorraine, Jefferson County, N. Y.; Lower Lorraine, Totman Gulf, Lorraine, N. Y.; Lorraine, Rome, N. Y.; Point Pleasant limestone, West Covington, Ky.; Eden, Cincinnati, Ohio.

Development of Cryptolithus bellulus.—As pointed out by Ruedemann (1926, p. 110) "The supposed Utica shale at Sixmile Creek near Rome is the Frankfort shale and contains *C. bellulus*." The young individuals from near Rome described by Beecher (1895 under the name *Trinucleus concentricus* may thus be referred to *C. bellulus*. Beecher's material contains a number of isolated cephala, which do not have the lower lamella of the fringe attached, and a few small pygidia (see plate 5, figs. 1, 7–9, 13). They may probably all be regarded as belonging to the meraspid period of the development.

The smallest cephala (pl. 5, fig. 8, 13), on which Beecher's figure 2, pl. 3 is based, have the glabella strongly carinate, with steep,

EXPLANATION OF PLATE 5

Untouched photographs. Figured specimens in the United States National Museum, unless otherwise stated (Y.P.M.—Peabody Museum, Yale Univeristy; M.C.Z.—Museum of Comparative Zoology, Harvard University; N.Y.S.M.—New York State Museum).

FIGS. *1, 7–9, 13, 14, 19, 21, 22, 25, 26, 28—Cryptolithus bellulus* (Ulrich). *8, 13*, Y.P.M., dorsal views, ×15. *1, 7*, Y.P.M., dorsal views, ×10, ×5. *25*, Holotype, dorsal view, ×4. *28*, Paratype, dorsal view, ×2. *19*, Anterior view of specimen from river quarries, West Covington, Ky., ×2. *21*, Dorsal view, Totman Gulf, Lorraine, N. Y., ×2. *14*, Ventral view of lower lamella, Ohio River, West Covington, Ky., ×2. *22*, N.Y.S.M. type no. 13288/2 of *Cryptolithus lorrainensis*, ×1. *26*, N.Y.S.M. type 13288/1 of *C. lorrainensis*, dorsal view, ×1. (p. 30)

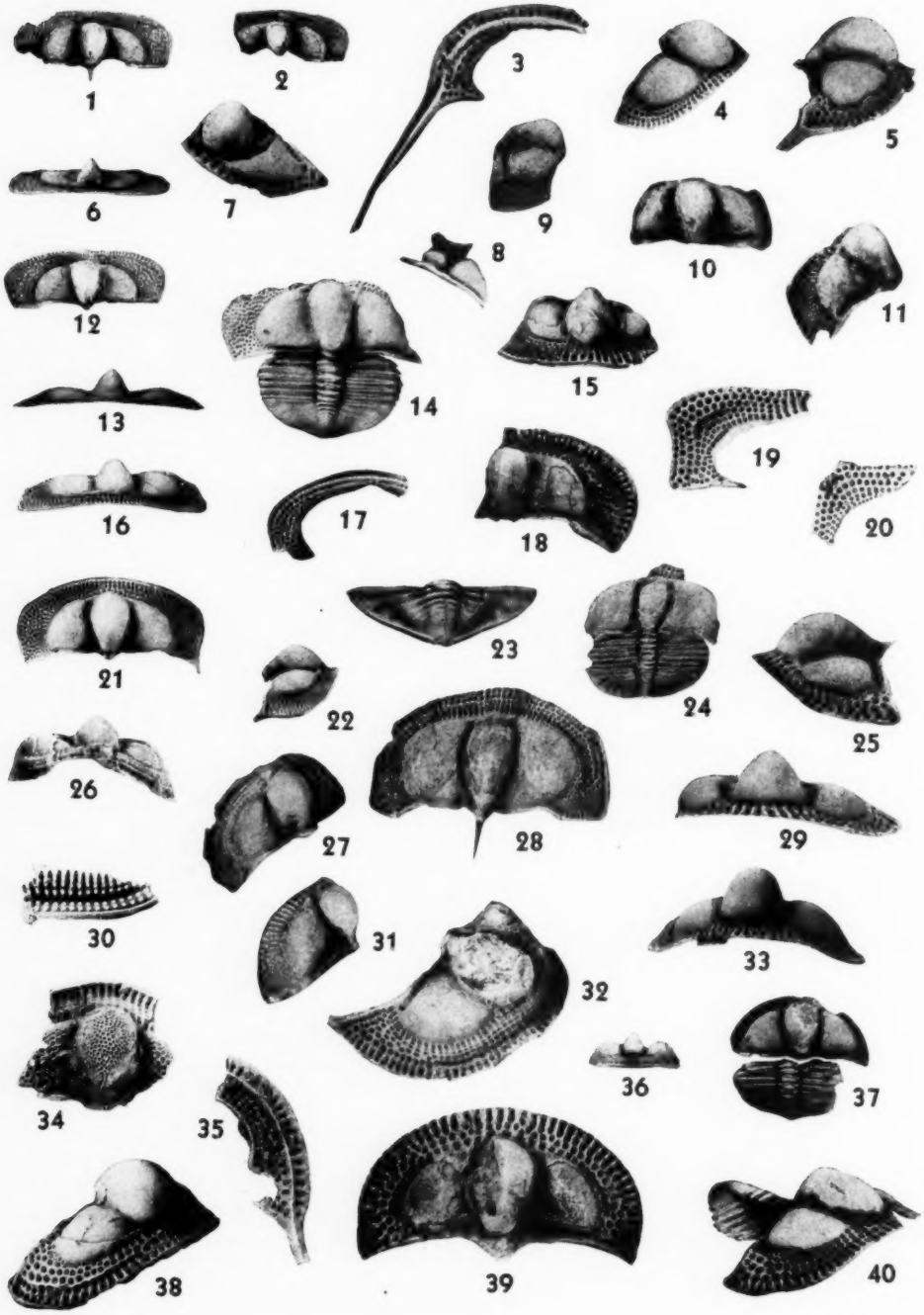
2, 15, 17, 18—Cryptolithus tesselatus Green. *2*, Dorsal view, Trenton limestone, Reedsville, Pa., ×2. *15*, Lateral view, 1 mi. east of Galway, Saratoga County, N.Y., ×2. *17*, Anterolateral view, top of Chambersburg limestone, Strasburg, Va., ×2. *18*, Anterior view, Trenton limestone, Poland Bridge, Russia, N.Y., ×2. (p. 29)

3, 5, 6, 10–12, 16, 20, 24—Cryptolithus fittsi Ulrich and Whittington, n. sp. (p. 36)

4, 29, 27—Paratrinucleus acervulosus (Raymond). *29*, Holotype, M.C.Z., dorsal view, ×2. *4*, Same slab as holotype, ventral view of lower lamella, ×2. *27*, Dorsal view, Athens, south of Luster's Gate, 3½ mi. east of Blacksburg, Va., ×2. (p. 27)

23—Trinucleus murchisoni Salter. Dorsal view, Llanvirn, Tasgar quarry, near Shelve, Shropshire, England, ×2. (p. 23)

Whittington, Trinucleidae



Whittington, Trinucleidae

flat sides. The highest point is a little posterior to half the length, gentle frontal slope and descending steeply posteriorly to the shallow occipital furrow. The alae are large, gently convex, not crossed by the occipital furrow, separated from the rest of the glabella by the broad shallow furrows which unite anteriorly with the axial furrows and posteriorly with the occipital furrow. Lateral eye tubercles large, with strong eye lists running anteromedially into the axial furrows. Cheek lobes with coarse reticulate ornament. The fringe, which Beecher regarded as not yet developed (p. 308), is narrow, with one row of pits, a few additional pits posteriorly. The external margin of the upper lamella is gently convex and comparatively wide. Genal angles well in advance of the posterior border.

With increasing size (pl. 5, figs. 1, 7) the highest point of the glabella moves forward, but the carinate form and the steep, flat sides are retained. The alae are reduced in both length and width, and the lateral eyes are situated closer to the glabella, and the eye lists consequently shorter. The fringe increases in width with the appearance of four complete rows of pits, with I_4 reaching forward in the largest specimen to about the eighth pit of I_3 from the axial furrow. This

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EXPLANATION OF PLATE 6

Untouched photographs. Figured specimens in the United States National Museum, unless otherwise stated (Y.P.M.—Peabody Museum, Yale University; M.C.Z.—Museum of Comparative Zoology, Harvard University; N.Y.S.M.—New York State Museum).

FIGS. *1, 2, 6, 12–14, 16, 17, 21, 22.*—*Cryptolithoides ulrichi* Whittington, n. gen., n. sp. *21, 16, 22,* Holotype, dorsal, anterior and lateral views, ×2. *14,* Paratype, dorsal view, ×2. *17,* Paratype, ventral view of lower lamella, ×2. *1, 2, 12,* Dorsal, *6,* anterior, view, Witches Hole, Arbuckle Mountains, Okla., ×4. *13,* Small holaspid, anterior view, same slab as holotype, ×3. (p. 38)

18—*Cryptolithoides ulrichi* Whittington, n. gen., n. sp. Dorsal view of rubber mould of external cast of incomplete cephalon, foothills of Santiago Range, Brewster County, Texas, ×4. (p. 38)

4, 5, 33, 37—*Cryptolithus convexus* Ulrich and Whittington, n. sp. *5, 33,* Holotype, lateral and anterior views, ×2. *37,* Paratype, dorsal view, ×3. *4,* Paratype, anterolateral view, ×2. (p. 35)

3, 23, 25, 29, 39—*Cryptolithus carinatus* Ulrich and Whittington, n. sp. *39,* Holotype, dorsal view, ×2. *25, 29,* Paratype, lateral and anterior view, ×2. *3,* Paratype, ventral view of lower lamella, ×2. *23,* Paratype, dorsal view, ×2. (p. 34)

38, 40—*Cryptolithus tesselatus* var. *quadrilineus* Whittington, n. var. *38,* Holotype, anterolateral view, ×2. *40,* Anterolateral view of another individual, Swatara Gap, Lebanon County, Penna., ×2. (p. 30)

15—*Cryptolithus* n. sp. Anterior view, Viola limestone, 3¼ mi. northwest of Dougherty, Okla. ×1. (p. 37)

9, 10—*Cryptolithus* (s.l.) *welleri* Endo. Syntype, lateral and dorsal views, ×4. (p. 40)

11—*Cryptolithus* (s.l.) *multiseriatus* Endo. Holotype, posterolateral view, ×4. (p. 39)

19—*Marrolithus favus* (Salter). M.C.Z., dorsal view of portion of upper lamella of fringe, Llandeilo, old quarry, near Dynevor Park, near Llandeilo, South Wales, Great Britain, ×2. (p. 24)

20—*Marrolithus* sp. Dorsal view of portion of upper lamella of fringe, Spy Wood grit, Chirbury District, West Shropshire, England, ×2. (p. 24)

24, 28—*Lloydolithus lloydi* (Murchison). Dorsal views, Belton Quarry, Shropshire, England, ×2. (p. 24)

7, 8—*Novaspis elevata* (Cooper and Kindle). *7,* Y.P.M., anterolateral view of incomplete cephalon, Priest's Road, about 2 mi. west of Percé village, Gaspé Peninsula, Quebec, Canada, ×2. *8,* Y.P.M., posterolateral view of part of rubber mould from counterpart of *7,* showing glabellar furrows, ×2. (p. 40)

26, 27, 30–32, 34, 35—*Tretaspis reticulatus* Reudemann. *26, 27,* N.Y.S.M. type 14281/3, anterior and laterodorsal views, Rysedorph conglomerate, Rysedorph Hill, Rensselaer County, N.Y., ×2. *31,* N.Y.S.M. type 14280/1 (type of *T. diademata*), laterodorsal view, same locality as *26, 27,* ×2. *32,* Anterolateral view, Athens, 1½ mi. east of Tenth Legion, Va., ×2. *34,* Dorsal view of incomplete cephalon, ×4, *30,* Anterior of portion of lower lamella, ×5. *35,* Ventral view of portion of lower lamella, ×5, upper Chambersburg, road to Cherry Grove, 4 mi. northwest of Linville Station, Va. (p. 28)

36—*Tretaspis cerioides* (Angelin). Y.P.M., anterior view of meraspid cephalon, sea cliffs on the southern flank of Mt. Joli, 75 feet south of fault contact, Percé village, Gaspé Peninsula, Quebec, Canada, ×5. (p. 29)

largest specimen (pl. 5, fig. 1), although having a fringe very similar in number and arrangement of pits to the adult, except for the lack of I_5, still has the carinate glabella, alae, and lateral eyes. The genal angles are in advance of the posterior margin of the cephalon. This specimen may be at about degree 3 of the meraspid period.

The meraspid transitory pygidium (pl. 5, fig. 9), as remarked by Beecher (1895, p. 309), "is remarkable for the lack of definition between the axis and pleura." The median area is quite strongly convex, with three segmental divisions anteriorly. The pleural lobes are gently concave, with five segmental divisions demarcated by deep furrows. Laterally the lobes become smooth and flat, with a distinct marginal furrow. This transitory pygidium may be compared with that of the early meraspid degrees of *Onnia ornatus* (Whittington, 1940, figs. 3, 4, 5).

Cryptolithus carinatus Ulrich and Whittington, n. sp.

Plate 6, figures 3, 23, 25, 29, 39

Cephalon subsemicircular in outline, about twice as wide as long. Glabella clavate, markedly carinate in anterior view, standing well above the cheek lobes. Median tubercle present. One pair of glabellar furrows represented by subciruclar pits situated immediately in front of the extremities of the occipital furrow. Occipital furrow broad, shallow, straight, with lateral pits distinct, elongate. Occipital ring low, broad, with short occipital spine directed backwards and approximately horizontally. Axial furrows straight, broad, shallow, with small circular anterior pits situated on the glabellar side of the furrows. Arcuate encroachment of glabella into fringe. Cheek lobes about as long as broad, posterolateral margins rounded, gently and evenly inflated. Lateral eye tubercles absent. Posterior marginal furrow broad, shallow, posterior margin elevated, widening laterally to form a support to the fringe.

Fringe rather broad, inclined gently ventrally, and somewhat bent upwards at the lateral margins. Prolonged posteriorly a little beyond the rest of the cephalon. Upper lamella showing the following arrangement of pits:

E_1 marginal, with very strong radial plate separating the pits. About 20–24 pits on each side. I_1 with 19–24 pits on each side, I_2 with 17–22. I_3 rarely with two pits missing, or completely continuous, 16–20 pits on each side. I_4 arising at the fifth to eighth pit of I_3 from the axial furrow. I_5 present around the posterolateral margins of the cheek lobes. A number of additional pits at the posterior margin. The pits of E_1 to I_3 are approximately of the same size. The arrangement of the pits is in concentric rows, with occasional interruption laterally by an intercalated pit. There is a tendency to radial arrangement in front of the glabella, with wide, slightly raised radial ridges, but this is interrupted either by an intercalated pit in I_2 or by a pit intercalated in both E_1 and I_1 in radial arrangement with each other. E_1 and I_1 are in radial arrangement with each other, with occasional interruption laterally. Posteriorly the pits form an irregular network, but the radial ridges in E_1 are retained. Lower lamella with corresponding arrangement of pits. A very strong girder between E_1 and I_1 with prominent terrace lines, especially deep anteriorly, and continuous with the genal spine. Genal spines long, flexed outwards. Concentric ridge situated on the inner edge of the lower lamella anteriorly, laterally between I_3 and I_4, absent posteriorly. Pits without arrangement in radial sulci. Anteriorly the lamella is strongly flexed upwards in front of the girder.

Thorax unknown.

Pygidium associated with the material is subtriangular in outline, about three times as wide as long. Rachis gently convex, bounded by very shallow axial furrows, narrowing posteriorly, first five segments distinct, some 10 more indicated. Pleural lobes convex axially, posterolaterally depressed concave, anterolaterally flat, three segments indicated, the first with pleural furrows, the next two without, further segments faintly indicated. Narrow elevated border, margin steep, with terrace lines.

The dimensions are as follows:

	Holotype	Other specimens	
Length of cephalon	9.7	8.5	
Width of cephalon	20.6	18.0	
Length of pygidium			4.5
Width of pygidium			12.8

Types.—U. S. Nat. Mus. Holotype, incomplete cephalon from Viola limestone, 1¼ mi. northeast of Springer, Okla. Paratypes, lower lamella and incomplete cephalon from near top of Viola limestone, 2 mi. northeast of Springer, and pygidium from Viola limestone, 5 mi. southwest of Ardmore, Okla.

Other localities.—Upper one-third of Viola limestone, 3½ mi. northwest of Dougherty, Okla.

Discussion.—This species is distinguished from *Cryptolithus convexus*, n. sp., by the greater number of concentric rows of pits, and especially by the carinate glabella, which encroaches far less into the fringe. The number and arrangement in rows of the pits is similar to that of *C. tesselatus* var. *quadrilineus*, n. var., but is much less regular and does not show the concentric ridge between I_1 and I_2. Small individuals show coarse reticulation on the cheek lobes, but there is none preserved on the larger specimens on which this description is based.

Cryptolithus convexus Ulrich and Whittington, n. sp.
Plate 6, figures 4, 5, 33, 37

Cephalon subsemicircular in outline. Glabella clavate, very strongly convex and standing high above the cheek lobes, coarsely reticulate in the median and posterior portions. Median tubercle present. One pair of glabellar furrows represented by circular pits situated just within the axial furrows and immediately in front of the occipital furrow. Occipital furrow straight, broad, anterior slope markedly steepest, lateral pits distinct, elongated. Occipital ring narrow, with thornlike spine directed backwards and nearly horizontally. Axial furrows very shallow, broad, curving inwards posteriorly, with anterior pits. Preglabellar furrow practically absent, considerable arcuate encroachment of the glabella into the fringe. Cheek lobes about as long as broad, posterolateral margins rounded, evenly inflated, descending steeply to the fringe, and bent sharply down to the shallow posterior marginal furrows. Coarse reticulate ornament, no lateral eye tubercles. Posterior border of the cephalon a narrow elevated rim, widening laterally to form a support to the fringe.

Fringe narrow, tilted gently ventrally, widening and more steeply tilted laterally prolonged posteriorly beyond the rest of the cephalon. Upper lamella showing the following arrangement of pits:

E_1 marginal, with about 24 pits, separated by radial plates. I_1 with about 24 pits, of the same size as E_1. I_2 with about 22 pits. I_3 of small pits beginning at about the fifth pit of I_2 from the axial furrow. Additional small pits within I_3 at the posterolateral margins of the cheek lobes. Concentric arrangement of the pits in the fringe marked, disappearing only at the posterior margin. Radial arrangement very strong anteriorly to the glabella, where wide elevated radial ridges separate the pits. In front of the cheek lobes the radial arrangement is strong, anterolaterally the radii are flexed somewhat forwards. Laterally the radial arrangement is lost, and posteriorly the pits tend to be large and form an irregular network. Lower lamella not well known, pits corresponding to upper, girder between E_1 and I_1, bent sharply up anterior to it, and concentric ridges between I_1 and I_2, and laterally between I_2 and I_3. Girder and ridges showing terrace lines. Genal spine flexed outwards somewhat.

Thorax and pygidium known from one small whole specimen (pl. 6, fig. 37). Six segments. Axial lobe about one-fifth the width of the thorax. Axial ring convex, about one-half the length of the pleurae, articulating furrow broad, deep. Articulating half-ring elevated. Axial furrows shallow, with shallow articulating joint pits. Pleurae flat, bent sharply down at the extremities. Pleural furrow broad, rather deep, widening laterally.

Pygidium subtriangular in outline, a little more than twice as wide as long. Rachis moderately convex, bounded by shallow axial furrows, narrowing posteriorly, first three segments distinct, a further four indicated. Pleural lobes flat, five segments indicated by the pleural furrows. Narrow elevated border, margin steep.

The dimensions are as follows:

	Holotype	Paratype	Other cephala	
Length of cephalon	7.7	2.7	c7.7	4.6
Width of cephalon	15.7	6.3	c15.0	10.7
Length of thorax		1.5		
Width of thorax		4.9		
Length of pygidium		1.1		
Width of pygidium		4.0		

Types.—U. S. Nat. Mus. Holotype, in-

complete cephalon; paratypes, an incomplete holaspid and two incomplete cephala, from boulders of the Viola limestone in the Caney shale, north base of Winding Stair Mountain, Oklahoma.

Other localities: Viola limestone, one mile west of Overbrook, Okla.

Discussion.—The species is very close to *Cryptolithus tesselatus*. The glabella of *C. convexus* is rather more convex and encroaches further into the fringe than that of Green's species. In number of pits and their arrangement the two species are very similar, but *C. convexus* does not have the strong concentric ridge between I_1 and I_2 which is characteristic of *C. tesselatus*, I_1 is not depressed, nor are the radial plates between pits in E_2 so prominent. The reticulate ornament on the glabella and cheek lobes is shown by the small holaspid, but is not preserved on the larger adults.

CRYPTOLITHUS FITTSI Ulrich and Whittington, n. sp.
Plate 5, figures 3, 5, 6, 10–12, 16, 20, 24

Cephalon subsemicircular in outline, about 2½ times as wide as long. Glabella clavate, strongly convex, standing high above the cheek lobes, median tubercle present. One pair of glabellar furrows represented by circular pits situated immediately in front of the extremities of the occipital furrow. Occipital furrow straight, shallow, with elongate lateral depressions. Occipital ring narrow, with short spine. Axial furrows broad and shallow, with small anterior pits. Arcuate encroachment of glabella into fringe. Cheek lobes about as broad as long, rounded posterolateral margins, evenly inflated, without lateral eye tubercles. Posterior marginal furrow shallow. Posterior margin narrow, elevated, widening laterally to form a support to the fringe.

Fringe narrow anteriorly, increasing considerably in width laterally, tilted gently ventrally anteriorly, more steeply laterally, the outer portion flexed upward somewhat anteriorly and anterolaterally, prolonged beyond the rest of the cephalon. The pits in the fringe are small and relatively numerous. E_1 marginal, with 26–30 pits on each side. In upper lamella, I_1 is in concentric and, except laterally, radial arrangement with E_1, with low, wide radial ridges separating the pits. Short raised radial plates may be developed on these ridges, and in concentric arrangement with, or immediately within, E_1. I_1 has 23–29 pits on each side. Anteriorly, within I_1 there are two rows of pits, I_2 and I_3, in radial and concentric arrangement with E_1 and I_1, with the radial ridges between pits. This radial arrangement is sometimes disturbed by intercalation of pits. I_3 may be complete, or have up to five pits missing in front of the glabella. Laterally, within I_1, the arrangement of pits is irregular, forming a network. A new row of pits arises from I_3 at the fourth to ninth pit from the axial furrow. A number of additional pits at the posterolateral margins of the cheek lobes. Lower lamella with corresponding arrangement of pits, strong girder showing terrace lines, anteriorly to which the lamella is flexed upwards. Sometimes concentric ridge between I_1 and I_2, which disappears laterally, and anteriorly a concentric ridge on the inner edge which laterally is outside the innermost row of pits. Genal spines long, flexed outwards, channel continuous with the girder.

Thorax of six segments. Axial ring strongly convex, about one-fifth the width of the thorax, appendifers distinct, deep. Axial furrows shallow, with shallow articulating-joint pits. Pleurae with shallow pleural furrows widening laterally, and sharply bent down at their extremities.

Pygidium subtriangular in outline, two and one-half to three times as wide as long. Rachis quite strongly convex, narrowing gradually posteriorly, first four or five segments distinct, with appendifers on first deep, shallower on second, and absent posteriorly; some 13 further segments indicated on one specimen. Axial furrows shallow pleural lobes gently convex axially, flat laterally, up to five segments indicated, the first with shallow pleural furrows. Margin of pygidium steep, showing terrace lines.

The dimensions are as follows:

	Holotype	Paratype	Other cephala	
Length of cephalon	5.05	c10.4	8.4	6.0
Width of cephalon	12.0	26.9	19.8	14.8
Length of thorax		5.7		
Width of thorax		18.8		
Length of pygidium		6.4		
Width of pygidium		17.3		

Types.—U. S. Nat. Mus. Holotype, incomplete cephalon; paratype, incomplete holaspid, from chert boulder in the Johns Valley shale, Johns Valley, Ouachita Mountains, Okla.

Other localities.—Viola limestone: 350 yards north of south border of McAlister quad., Okla.; vicinity of Overbrook and Ardmore, Okla. Caney shale: SW ¼ sec. 18, T. 1 S, R. 14 E, Oklahoma; Winding Stair Mountain, Okla.; 1½ mi. south of Sulphur, Okla., on highway 18, sec. 11. Some material in the United States National Museum collections from Middle Ridge at head of Pete Hanson Creek, north side of Roberts Creek Mountain, Roberts Mountain quadrangle, Nevada, contains a cryptolithid which may belong to this species.

Discussion.—The pits in the fringe of this species are rather numerous and small, and the radial plates in E_1, when present, are small, and concentric arrangement of pits is absent laterally within I_1. In these respects the species approaches *Cryptolithoides ulrichi*, n. gen., n. sp., but it lacks the anterolateral angulation of the fringe. In addition the young stages of *C. fittsi* show the reticulate ornament on the glabella and cheek lobes (see below), and this ornament is absent in *Cryptolithoides*.

The material from near Sulphur, Okla., is exceptional in that all the specimens show the fringe with I_3 complete anteriorly, the radial plates in E_1 are always present, and there are a few more pits in the lateral portions of the fringe. The material available is not sufficient, however, to warrant specific or varietal distinction of the forms from this locality.

The material contains a number of small cephala, the smallest of which is 1.3 mm. in length (pl. 5, fig. 5). Only a small portion of the fringe, anterior to the axial furrow, is present, and shows four concentric rows of pits. The glabella is carinate, standing high above the cheek lobes, with steep, flat sides. No reticulate ornament observed. The axial furrows widen posteriorly, and at the base of the glabella are the small convex alae, not crossed by the occipital furrow, and forming a continuous crescentic curve with the occipital ring. Occipital spine very short. The glabella furrows and lateral pits are shallow, situated just within the alae. The lateral eye tubercles are large, situated at about half the length of the glabella at the axial edge of the cheek lobes. The cheek lobes and axial furrows show a coarse reticulate ornament.

A cephalon of length 1.5 mm., width approximately 4.1 mm. (pl. 5, fig. 6) is very similar to the previous. The glabella shows reticulate ornament on the frontal slope. The fringe is without the innermost row of pits, and I_3 has five pits missing in front of the glabella. Anterior to the glabella and cheek lobes the arrangement of the pits is in four concentric rows, radial anterior to the glabella. Laterally within E_1 the arrangement is irregular.

The cephala of about 2 mm. in length (pl. 5, figs. 11, 12) show the fringe very similar to the adult, the innermost row of pits present but not extending quite so far forward, and the radial elevations between E_1 and I_1 are not developed. The glabella shows reticulate ornament on the frontal slope and the median area. The eye lists are reduced to low ridges in the axial furrows. The alae are smaller and the axial furrows narrower posteriorly.

Specimens of about 2.5 mm. in length (pl. 5, fig. 16) show the radial elevations on the fringe, the glabella is carinate, alae still further reduced, reticulate ornament on the cheek lobes fairly prominent, the eye lists still being distinct.

CRYPTOLITHUS, n. sp.
Plate 6, figure 15

Three incomplete cephala from the Viola limestone, 3¼ mi. northwest of Dougherty, cannot be placed in any of the above species. The characters are as follows:

Cephalon subsemicircular in outline, a little more than twice as wide as long. Glabella clavate, very strongly convex, greatest width about twice that at the base, posterior half, behind the median tubercle, carinate, with steep, nearly flat sides. One pair of glabella furrows, represented by shallow pits situated immediately anterior to the extremities of the occipital furrow. Occipital furrow straight, very shallow. Occipital ring narrow, rather strongly convex. Axial furrows broad, small anterior pits. Arcuate encroachment of glabella into fringe. Fine reticulate ornament on the frontal slope and the carinated posterior portion of the gla-

bella. Cheek lobes about as long as broad, with rounded posterolateral margins, strongly inflated, descending almost vertically to the fringe, without lateral eye tubercles. Fine reticulate ornament in the median area. Posterior marginal furrow shallow, broad. Posterior margin narrow, elevated, widening considerably laterally to form a support to the fringe.

Fringe broad, flat, gently tilted ventrally anteriorly, quite steeply laterally, prolonged posteriorly a considerable distance beyond the rest of the cephalon. The upper lamella shows the two outer rows of pits, E_1 and I_1, in concentric and radial arrangement, with, anteriorly and anterolaterally, very strong raised radial plates separating the pits. Anteriorly there are three concentric rows of pits, I_2–I_4, the concentric arrangement being obscured by irregular displacement of pits. I_5 arises at about the seventh pit of I_4 from the axial furrow, and laterally there are numerous additional pits in the fringe, the posterior margin showing some 11 pits. The lower lamella with strong girder between E_1 and I_1, concentric ridge between I_1 and I_2 and within I_4.

Thorax and pygidium unknown.

Discussion.—The material is too little and too fragmentary to justify the designation of a specific name, but it is clear from the characters of the fringe and the glabella, and the convexity of the cephalon that the material represents a species different from the others described from Oklahoma. One of the cephala is only 1.5 mm. in length. The fringe is very similar to the adult, the glabella very strongly carinate, the cheek lobes showing very prominent eye tubercles and eye lists situated at the axial side of the lobes at about half the length of the glabella.

Genus CRYPTOLITHOIDES
Whittington, n. gen.
CRYPTOLITHOIDES ULRICHI Whittington,
n. gen., n. sp.
Plate 6, figures, 1, 2, 6, 12–14, 16,
17, 21, 22

Cephalon subrectangular in outline, a little more than twice as wide as long, greatest width at the anterolateral margin of the fringe. Glabella clavate, moderately convex. Small median tubercle. One pair of glabellar furrows represented by very small circular pits situated just within the axial furrows and a short distance anterior to the occipital furrow. Occipital furrow shallow. Occipital ring with spine. Axial furrows straight, moderately deep, small anterior pits. Cheek lobes about as long as broad, rounded posterolateral margins, without lateral eye tubercles or reticulate ornament. Posterior marginal furrow shallow. Posterior margin elevated, narrow, widening laterally to form a support to the fringe.

Fringe narrow anteriorly, increasing considerably in width anterolaterally and laterally, with consequent anterolateral angulation of the cephalic margin; gently inclined ventrally, slightly flexed upwards at the anterior margin. Pits in the fringe small and relatively numerous, one row exterior to the girder. In the upper lamella, the two outer rows of pits, E_1 and I_1, are in concentric rows, I_1 rather irregular posteriorly, with a distinct low concentric ridge separating them; anteriorly the arrangement is also radial, sometimes interrupted by intercalation of a pit or pits. Short raised radial plates sometimes developed in E_1. E_1 with usually about 31 pits (range 29–38) on each side. Anteriorly to the glabella I_2 and I_3 are in radial arrangement with E_1 and I_1, with low radial ridges between the pits. About four pits of I_3 missing in this region. Outside this region the pits within I_1 are without any arrangement and form an irregular network. At the anterolateral area of the fringe the pits just within I_1 tend to be rather widely separated from each other. Lower lamella with girder, deepest anteriorly, concentric ridge developed within I_1 anteriorly, concentric ridge on inner margin. Genal spines long, flexed strongly outwards.

Thorax of six segments. Axial ring convex, appendifers deep. Axial furrows distinct, shallow, with articulating joint pits. Pleurae sharply bent down at the extremities, pleural furrows shallow, widening laterally.

Pygidium subtriangular in outline, about three times as wide as long. Rachis gently convex, narrowing posteriorly, first three segments distinct, appendifers on first, about seven further segments indicated. Pleural lobes very slightly convex axially. First segment indicated. Margin steep.

The dimensions are as follows:

	Holotype	Paratype	Other cephala				
Length of cephalon	7.0		7.0	6.6	7.7	9.5	7.2
Width of cephalon	12.5		14.4	15.5	17.4	23.2	16.7
Length of thorax		2.9					
Width of thorax		9.6					
Length of pygidium		2.6					
Width of pygidium		8.6					

Types.—U. S. Nat. Mus. Holotype, cephalon; paratype, lower lamella; from Viola limestone, 3 mi. north of Buckhorn, Okla. Paratype, thorax and pygidium, from 1 mi. southeast of Sulphur, Okla.

Other localities.—Viola limestone, 4 mi. northwest, 3 mi. east, 3¼ mi. northwest of Dougherty, Okla.; 2 mi. east of Rainy Mountain, Okla.; highway 77, in creek, about 30 feet above Simpson contact, just south of Arbuckle camp: Witches Hole, Arbuckle Mountains, Okla. A specimen from the Ordovician, foothills of the Santiago Range, Brewster Co., Texas, (pl. 6, fig. 18) belongs to this genus and may be the same species.

Discussion.—The material contains a number of small cephala, the smallest (pl. 6, fig. 2) being a little over 1.5 mm. in length, and some 6 mm. in width. The glabella is very strongly carinate, with steep, flat sides, no reticulate ornament. Axial furrows shallow, rather large anterior pits, and broadening posteriorly. Posterior portion of the glabella not preserved. Cheek lobes moderately inflated, quite smooth, with lateral eye lists arising on the axial margin at about half the length of the glabella, and crossing the axial furrow. The characters of the fringe are very similar to those of the adult. E_1 with over 30 pits.

A second cephalon of similar size (pl. 6, fig. 1) shows the posterior portion of the glabella. The alae are small, gently convex, not crossed by the occipital furrow and enclosing the lateral pits and the shallow circular glabellar furrows.

Cephala of length 2.0 to 2.5 mm. (pl. 6 figs. 6, 12) are very similar. The alae are very small, occipital spine long. Eye lists still further reduced, almost absent. No trace of reticulate ornament.

These small cephala are more nearly rectangular in outline than the adult. The carinate glabella, the eye lists, and the early development of a fringe with the characters of the adult, are features in common with the young stages of other genera of the Cryptolithinae. The absence of reticulate ornament on the cephalon and cheek lobes, which is so characteristic of *Cryptolithus*, is striking. The material appears to be suitable for the preservation of such reticulate ornament, where it is present. It is possible that the ornament was present in the first degrees, and was lost very early in the development, but this is perhaps unlikely.

As noted above, *Marrolithus* and *Cryptolithoides* are characterized by the anterolateral angulation of the cephalic margin and the occurrence of additional pits in this region. In *Marrolithus* the pits are concentrically arranged, and one or two rows adjacent to the anterolateral margins of the cheek lobes bifurcate anteriorly by division of pits in radial sulci and reunite posteriorly in the same manner (pl. 6, figs. 19, 20). The pits in I_1–I_3 are frequently surrounded by raised plates anterolaterally, producing a honeycomblike effect (cf. Salter, 1853, pl. 7, p. 6). *Cryptolithoides* is quite different in that the pits adjacent to the anterolateral margins of the cheek lobes are irregular in arrangement, and there is never division of pits in radial sulci, and the margins of the pits in I_1–I_3 are not elevated. It is not known whether *Marrolithus* has the reticulate surface ornament.

Cryptolithus (s.l.)[1]
Cryptolithus (s.l.) multiseriatus
Endo 1932
Plate 6, figure 11.

Endo, *1932*, pp. 110–111, pl. 39, fig. 2.

The holotype, U.S.N.M. 83764, is a small half cephalon, length approximately 2.5 mm., preserved in limestone. The glabella is carinate in anterior view, posteriorly small weakly convex alae, not crossed by the occipital furrow, and enclosing the shallow lateral pits and the shallow subcircular pits of the first glabellar furrows. On the axial edge of the cheek lobe, at about half the length of the glabella, a distinct lateral eye tuber-

[1] I.e., a genus possibly within the Cryptolithinae.

cle. Genal caeca very distinct, having a slightly curved course from the eye tubercle to the posterolateral margin of the cheek lobes, then curving sharply back to cross the posterior marginal furrow and abut against the posterior margin.

The fringe is very narrow anteriorly, with anterolateral angulation of the margin, and with rather numerous, irregularly arranged pits.

The holotype specimen may well be an immature individual, since it has the carinate glabella, alae, and lateral eye tubercles. The genal caeca are unusually distinct. The fringe is very different from that of *Cryptolithus*, and recalls *Cryptolithoides*. The latter genus, however, has cheek lobes without reticulate ornament.

CRYPTOLITHUS (s.l.) WELLERI Endo
Plate 6, figures 9, 10

ENDO, *1932*, p. 111, pl. 39, figs. 3–8.

Only one specimen in the United States National Museum is preserved in limestone, the remainder are plaster casts. The former is an incomplete cephalon, length approximately 2.5 mm. The cheek lobes show the lateral eye tubercles, situated at the axial edge at about half the length of the glabella. Genal caeca prominent, arising within the axial furrows a short distance posterior to the lateral eye tubercles, running along the posterior margin of the cheek lobes to the posterolateral angles, and swinging sharply across the posterior marginal furrow to abut against the posterior margin.

The fringe steeply inclined and with large pits in the outer rows of the upper lamella.

This specimen of *C.* (s.l.) *welleri* may be an immature individual, but it seems to be distinguished from the genera of the Cryptolithinae in having two pairs of glabellar furrows, and the steep fringe, which is very narrow anteriorly. The genal caeca are unusually prominent, and have a different course from those of *C.* (s.l.) *multiseriatus*. These two South Manchurian forms are distinct from each other and from other genera of the Trinucleidae, but the material available is insufficient as a basis for new genera.

Genus NOVASPIS Whittington, n. gen.
NOVASPIS ELEVATA (Cooper and Kindle)
Plate 6, figures 7, 8

Tretaspis elevata COOPER and KINDLE, *1936*, pp. 361–362, pl. 52, figs. 19, 25, 28.

I have collected one incomplete cephalon and its counterpart from the crystalline limestone along Priest's Road, Percé, Quebec (locality L, Cooper and Kindle, 1936, p. 349). A few points may be added to the original description:

Glabella with median tubercle. Two pairs of glabellar furrows (see pl. 6, fig. 8), the first pair shallow circular pits situated at the posterolateral margin of the pseudofrontal lobe. Immediately posterior to the latter the "neck" is depressed by a broad, shallow transverse furrow, posteriorly to which it is moderately convex. Second pair of glabellar furrows shallow, situated at the lateral margins of the posterior portion of the "neck," and opening forwards into the transverse furrow and posteriorly into the occipital furrow. No occipital spine. Cheek lobes smooth, without lateral eye tubercles. Unfortunately neither the holotype nor my specimen give any information on the structure of the lower lamella of the fringe.

The trinucleid from the Whitehouse group, Scotland, named by Reed *Trinucleus albidus* (1914, pp. 3–4, pl. 1, figs. 1–2) is certainly not a *Trinucleus*, but appears from the illustrations and descriptions to be related to *Novaspis*. The glabella, although crushed, is similar in shape, with median tubercle and indistinct glabellar furrows. The pseudofrontal lobe shows reticulate ornament (Reed, 1914, p. 3). The cheek lobes are smooth and without lateral eye tubercles, the fringe with two rows of pits, on the upper lamella in radial sulci anteriorly, and becoming separate laterally.

LITERATURE

BANCROFT, B. B., *1929*, Some new species of *Cryptolithus* (s.l.) from the Upper Ordovician. *Manchester Lit. Phil. Soc., Mem. and Proc.*, vol. 73, pp. 67–98.

——, *1933*, *Correlation tables of the stages Costonian-Onnian in England and Wales*. Privately printed.

BARRANDE, J., *1852*, *Système silurien de la Bohème*, vol. I. Prague and Paris.

BASSLER, R. S., *1919, Maryland Geol. Survey, Cambrian and Ordovician.*

BEECHER, C. E., *1895,* Structure and appendages of *Trinucleus: Am. Jour. Sci.,* vol. 49, pp. 307–311.

BORN, A., *1921,* Eine Untersilurfauna aus den Montaignes Noires (Central plateau): *Senckenbergiana,* Band 3, pp. 181–193.

BULMAN, O. M. B., *1931,* South American graptolites, with special reference to the Nordenskiold collection: *K. svenska vetensk. akad., Arkiv. för Zool.,* bind 22A.

COOPER, G. A., and KINDLE, C. E., *1936,* New brachiopods and trilobites from the Upper Ordovician of Percé, Quebec: *Jour. Paleontology,* vol. 10, pp. 348–372.

ELLES, GERTRUDE L., *1937,* The classification of the Ordovician rocks: *Geol. Mag.,* vol. 74, pp. 481–495.

——, *1939,* The stratigraphy and faunal succession in the Ordovician rocks of the Builth-Llandridod inlier, Radnorshire: *Geol. Soc. London, Quart. Jour.,* vol. 95, pp. 383–444.

ENDO, R., *1932,* The Canadian and Ordovician formations and fossils of South Manchuria: *U. S. Nat. Mus., Bull.* 164.

FOERSTE, A. F., *1924,* Upper Ordovician faunas of Ontario and Quebec: *Canada Geol. Survey, Mem.* 138.

GREEN, J., *1832, A monograph of the trilobites of North America.* Philadelphia.

KAY, G. M., *1937,* Stratigraphy of the Trenton group: *Geol. Soc. America, Bull.,* vol. 48, pp. 253–302.

KOBAYASHI, T., *1937,* The Cambro-Ordovician Shelly faunas of South America: *Tokyo, Imp. Univ., Fac. Sci. Jour.,* sec. 2, vol. 4, pt. 4, pp. 369–522.

LAKE, P., *1906,* Trilobites from Bolivia: *Geol. Soc. London, Quart. Jour.,* vol. 62, pp. 425–432.

LAMONT, A., *1935,* The Drummuck group, Girvan; a stratigraphical revision, with descriptions of new fossils from the lower part of the group: *Geol. Soc. Glasgow, Trans.,* vol. 19, pp. 288–334.

LEITH, E., *1938,* A Middle Ordovician fauna from the Venezuelan Andes: *Am. Jour. Sci.,* vol. 36, pp. 337–334.

MCCOY, F., *1846, Synopsis of the Silurian fossils of Ireland.*

——, *1849,* On the classification of some British fossil Crustacea: *Ann. and Mag. Nat. History,* ser. 2, vol. 4, pp. 392–415.

MURCHISON, R. I., *1839, The Silurian system.* London.

RAYMOND, P. E., *1920,* Some new Ordovician trilobites: *Harvard College, Mus. Comp. Zool., Bull.,* vol. 64, no. 2, pp. 273–296.

——, *1925,* Some trilobites from the lower Middle Ordovician of eastern North America: *idem,* vol. 67, no. 1, pp. 1–180.

REED, F. R. C., *1895,* New trilobites from the Bala beds of County Waterford: *Geol. Mag.,* dec. 4, vol. 2, pp. 49–55.

——, *1903,* The Lower Palaeozoic trilobites of the Girvan District, Ayrshire: pt. I, *Palaeont. Soc. Pub.*

——, *1912,* Notes on the genus *Trinucleus,* pts. I, II: *Geol. Mag.,* dec. 5, vol. 9, pp. 346–353, 385–394.

——, *1914a,* Op. cit., pt. III: *idem,* 6, vol. 1, pp. 349–359.

——, *1914b,* The Lower Palaeozoic trilobites of Girvan: *Palaeont. Soc. Pub., Suppl.*

RUEDEMANN, R., *1901,* Trenton conglomerate of Rysedorph hill and its fauna: *New York State Mus., Bull.* 49, pp. 3–114.

——, *1916,* The cephalic suture lines of *Cryptolithus* (*Trinucleus* auct.): *idem, Bull.* 189, pp. 144–148.

——, *1926,* Utica and Lorraine formations of New York, pt. 2: *idem, Bull.* 272, pp. 1–227.

SALTER, J. W., *1848,* Palaeontological appendix: *Great Britain Geol. Survey, Mem,* vol. 2, pt. 1.

——, *1853,* British organic remains: *idem,* dec. 7.

SCHUCHERT, C. and COOPER, G. A., *1930,* Upper Ordovician and Lower Devonian stratigraphy and paleontology of Percé, Quebec: *Am. Jour. Sci.,* vol. 20, pp. 161–176, 265–392.

STØRMER, L., *1930,* Scandinavian Trinucleidae, with special reference to Norwegian species and varieties: *Norske vidensk.-akad. Oslo, Skrifta,* I, *Math. Nat. Kl.,* no. 4.

STUBBLEFIELD, C. J., *1938,* The types and figured specimens in Phillips and Salter's Palaeontological Appendix . . . : *Great Britain, Geol. Survey, Summary Prog.* 1936, pt. 2, pp. 27–51.

——, *1939,* Some aspects of the distribution and migration of trilobites in the British Lower Palaeozoic faunas: *Geol. Mag.,* vol. 76, pp. 49–72.

ULRICH, E. O., *1878,* Description of some new species of fossils from the Cincinnati group: *Cincinnati Soc. Nat. History, Jour.,* vol. 1, no. 2, pp. 92–100.

WOODWARD, H., *1883,* Note on the nature of certain pores: *Geol. Mag.,* dec. 7, vol. 10, pp. 536–541.

WHITTINGTON, H. B., *1940,* On some Trinucleidae described by Joachim Barrande: *Am. Jour. Sci.,* vol. 238, pp. 241–259, pls. 1–4.

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TEREBRATULACEA OF THE CEDAR VALLEY BEDS OF IOWA

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ABSTRACT—Sixteen species of Terebratulacea from two families are described and illustrated. *Cranaena* is represented by 13 species of which seven are new. *Rensselandia* has three species, one new.

CRANAENA is a prominent genus in the Devonian of Iowa, as it occurs in all formations from the Independence to the Lime Creek. One species is present in the Independence, 16 in the Cedar Valley, six in the Shellrock and four in the Lime Creek. The upward decline in species foreshadows the disappearance of the genus in the Mississippian. In the number of species the genus rivals *Atrypa* and *Stropheodonta*, but in individuals it is not as common as either. Locally in one or two zones specimens are abundant but this is exceptional.

The genus is best developed in the Cedar Valley, as each zone has one or more species. They are good horizon markers for some zones but are less valuable in others because of scarcity of specimens. Two zones are especially notable, as each has several species and numerous individuals. The *profunda* zone, second above the base of the formation, has five species, none of which is abundantly represented. The most prolific horizon is found in the beds above the *waterlooensis* zone. From these strata six species have been recovered. One of them, *Cranaena iowensis* is abundant and gives its name to the zone. A single species, *Cranaena subglobosa*, is recurrent, as it is found in both the *cranaena* and *profunda* zones.

Most of the species described are confined to the Cedar Valley area in Iowa. Several have been reported from the extensions of the formation in Minnesota and Illinois. Savage has also described two species, *Cranaena maxima* Savage and *Cranaena elliptica* Savage, from the Cedar Valley in Illinois, which have not yet been recovered in Iowa. *Cranaena infrequens* Belanski from the northern area of the formation has not been included in this discussion, as that part of the outcrop was not considered in this series of papers on Iowa Cedar Valley brachiopods.

Detailed correlation of the Cedar Valley with formations of adjacent states cannot be made at this time, as many of its brachiopods remain to be described. It is hoped that the stratigraphic evidence afforded by these fossils may be summarized as soon as the fauna has been made known completely. However the correlative value of *Cranaena* and its species is not great, for few have been reported elsewhere. Two species in the Cedar Valley are reported by Branson from the Devonian of Missouri—*Cranaena iowensis* from the Callaway limestone, and *Cranaena romingeri* from the Mineola. The latter species also occurs in Michigan in the Partridge Point beds near Alpena and in the Traverse beds near Petosky. *Cranaena iowensis* is listed by Cleland in the Devonian of the Milwaukee area of Wisconsin.

From the basal part of the Devonian of Calhoun County, Illinois, six species of *Cranaena* have been described recently by Cooper and Cloud. Two of them, *Cranaena subcylindrica* Cooper and Cloud and *Cranaena romingeri* Hall, also occur in the *profunda* zone of the Cedar Valley. *Cranaena radiata* Cooper and Cloud is also near *Cranaena elia* Hall. These occurrences indicate that the basal beds of this Devonian section are to be correlated with the *profunda* zone of the Cedar Valley rather than with the *Cranaena iowensis* zone as suggested by Cooper and Cloud. This correlation is also further corroborated by the only known occurrence in the Cedar Valley of *Scutellum* at the top of the *profunda* zone in Iowa. Also beds carrying *Atrypa bellula* Stainbrook and its accompanying fauna occur above the *profunda* zone at each locality.

Rensselandia has a short vertical range in the Cedar Valley, as it occurs only in the upper part of the *profunda* zone. Scattered and sparse in most localities, disarticulated valves locally may be so abundant as to

form beds of *Rensselandia* coquina several feet thick. This condition is seen at several places near Center Point, Iowa. Of the three species described herein, only one, *Rensselandia missouriensis*, occurs elsewhere. It is in the lower part of the Callaway limestone and further emphasizes the equivalency of that formation to the Cedar Valley. Species of *Rensselandia* are known in the Hamilton of Pennsylvania and in the Devonian of the Ramparts of the Mackenzie in Canada. The genus seems to be indicative of late Middle and early Upper Devonian.

Species designated as S.U.I. are in the repository of the State University of Iowa. Those marked M.A.S. are in the writer's personal collection, which is to be deposited eventually in that institution. Several examples noted as in the Belanski collection are also at present in the University repository. The figures in the plates are all natural size. A few are slightly retouched.

Cross sections were made only of those species represented by numerous individuals. The posterior parts of selected examples were ground off gradually and studied closely to discover changes in internal structures. At variable intervals sketches were made at those points where changes seemed most significant. The sections, therefore, are not made at regularly measured intervals, as experience has shown that in the same species structural changes in the interior may appear at different distances from the beak. Most sections illustrate only the most posterior part of the pedicle valve, as there is little of significance beyond the point of disappearance of the septa. Most of the sections of the brachial valve are carried through that point where the hinge plate separates from the walls of the valve. Beyond this, only the crura are illustrated. The pedicle valve is always uppermost in the diagrams.

Family CENTRONELLIDAE Waagen

Genus RENSSELANDIA Hall

RENSSELANDIA JOHANNI Hall

Plate 8, figure 3; text figure 10B

Rensselaeria? johanni HALL, *1867*, Paleontology New York, vol. 4, p. 385, pl. 58A, figs. 10, 17, 19, 20.

Rensselandia johanni HALL, *1867*, *idem*, at end of description.

Newberria johanni HALL, *1891*, Contr. Canadian Paleontology, vol. 1, p. 237.

Newberria johannis HALL, *1891*, New York State Geologist, Tenth Ann. Rept., p. 8, pl. 6, figs. 1–11.

Newberria johannis HALL and CLARKE, *1893*, Paleontology New York, vol. 8, pt. 2, p. 262, pl. 78, figs. 10–16.

Newberrya johannis SCHUCHERT, *1897*, U. S. Geol. Survey, Bull. 87, p. 272.

Shell large, subcylindrical, subequally biconvex with the posterior half inflated, elongate oval in outline, with the posterolateral margins short and rounded, the anterolateral margins long and gently curved, and the short front margin nearly straight, broadest at or near the midlength. A medium-sized specimen measures 42.8 mm. in length, 28.2 mm. in width and 24.8 mm. in thickness. Other specimens are thinner than wide.

Pedicle valve regularly arched from beak to front, with the curvature increasing posteriorly; strongly arched transversely. Median anterior part elevated and slightly flattened, especially from the midpoint forward. Lateral slopes flat and descending abruptly to the lateral margins. Umbo rounded, not prominent, and projecting little beyond the hinge line. Beak small, short, and closely incurved over that of the opposite valve. Internal molds show the diductor muscle scars to be long, pear-shaped, and with narrow, elongate, fusiform adductors between. Brachial valve a little shorter and generally less convex than the pedicle valve and similarly shaped. Exterior of both valves marked by numerous fine concentric lines and occasional strong wrinkles of growth.

Locally, remains of this species occur in large numbers and make up the major part of beds several feet in thickness. The valves are usually separated and somewhat crushed and broken. Complete individuals are rarely secured.

Occurrence.—Cedar Valley limestone in the upper part of the *profunda* zone at Quasqueton, Fairbank, Center Point, Vinton and Brandon, Iowa.

Types.—The holotype is in the American Museum of Natural History. Hypotypes are S.U.I. 6–542 and M.A.S. 60 and 1252.

RENSSELANDIA CORDIFORME

Stainbrook, n. sp.

Plate 8, figures 2, 7, 8; text figure 10A

Rens laeria? johanni HALL, *1867*, Paleontology New York, vol. 4, pl. 58A, figs. 9, 18.

Shell above medium size, moderately biconvex, subcordiform in outline, with the anterolateral margins long and converging toward the front, longer than wide, with the greatest width posterior to the midlength. Measurements of the holotype, a nearly complete specimen, and of a paratype are: length 36.7 mm. and 39.7 mm.; width 31.8 mm. and 33.5 mm.; thickness 21.3 mm. and 25.5 mm.

Pedicle valve moderately convex, evenly arched from beak to front, highest at the midpoint, elevated and transversely flattened or gently convex along the midline, strongly curved beyond to the lateral margins. Beak large, short, projecting, a little incurved. Brachial valve nearly as convex as the pedicle, gently arched along the midline, with the curvature greater over the umbo, highest at the midpoint, elevated and gently convex along the midline, and sloping rapidly beyond to the lateral margins. Exterior of both valves marked by numerous fine lines of increment and occasional growth wrinkles.

Rensselandia cordiforme is proportionately shorter than *Rensselandia johanni*, is thinner and less cylindrical, differs greatly in outline, and has the greatest width posterior to the midlength. It is smaller than *Rensselandia missouriensis*, thinner, relatively longer in porportion to the width, and has a shorter and less rounded anterior margin.

Occurrence.—Cedar Valley limestone in the *profunda* zone at Littleton, Quasqueton, and Vinton, Iowa.

Type.—Holotype S.U.I. 6–436A; paratypes S.U.I. 6–436 and M.A.S. 1251.

RENSSELANDIA MISSOURIENSIS (Swallow)
Plate 8, figure 1; text figure 10C

Newberria missouriensis (Swallow MS.) HALL, *1891*, New York State Geologist, Tenth Annual Rept., p. 9, extract, pl. 5, figs. 10–12.
Newberria missouriensis BRANSON, *1923*, Devonian of Missouri, p. 93, pl. 18, figs. 1–4.

One complete individual may be referred to this species. It is a little crushed and distorted and not well-preserved. It measures 58.4 mm. in length, 48.5 mm. in width, 33.5 mm. in thickness. Compared with examples at the University of Missouri it has a longer and narrower pedicle valve. Growth lines on the posterior part of the shell, however, indicate that the width of the valves in the early stages was proportionately greater. A large specimen, broken anteriorly, is 55.5 mm. wide and 40 mm. thick. Broken valves indicate larger dimensions were attained, as one is more than 60 mm. wide.

The form is sparse in Iowa and occurs generally singly. At one or two places, e.g., near Fayette, a number of separate broken valves shows that it may have been locally more numerous.

Occurrence.—Cedar Valley limestone in the *profunda* zone at Fayette, Fairbank, and Solon, Iowa.

Types.—Hypotype S.U.I. 6–435.

Family DIELASMATIDAE Schuchert
Genus CRANAENA Hall and Clarke
CRANAENA IOWENSIS (Calvin)
Plate 7, figures 1–5, 25; text figure 8

Terebratula (*Cryptonella*) *iowensis* CALVIN, *1890*, Iowa State Univ., Lab. Nat. History, Bull., vol. 1, p. 174, pl. 3, fig. 4.
Cranaena iowensis HALL and CLARKE, *1893*, Paleontology New York, vol. 8, pt. 2, p. 297, pl. 80, figs. 36–39, pl. 83, fig. 41.
Cranaena iowensis SCHUCHERT, *1897*, U. S. Geol. Survey, Bull. 87, p. 188.
Cranaena iowensis CLELAND, *1911*, Wisconsin Geol. and Nat. History Survey, Bull. 21, p. 72, pl. 13, figs. 10, 11, not 8, 9.
Cranaena iowensis WELLER, *1914*, Mississippian Brachiopoda, p. 249, figs. a–j.
Cranaena iowensis BRANSON, *1922*, Devonian of Missouri, pp. 95–96, pl. 20, figs. 20–22.
Cranaena iowensis BELANSKI, 1928, Iowa Univ., Studies in Nat. History, vol. 12, no. 8, p. 7, fig. 2, pl. 1, figs. 1–8.

Shell medium-sized to large, strongly and subequally biconvex, longer than wide, with the greatest width at or near the midlength in mature specimens or in front of it in old examples, typically subpentagonal in outline, with the postero- and anterolateral margins rounded and the front margin nearly straight. Anterior commissure slightly sinuous. Measurements of the holotype and three hypotypes are: length 24.6 mm., 24.8 mm., 23.1 mm. and 22.3 mm.; width 21.6 mm., 22.3 mm., 18.9 mm. and 19.7 mm.; thickness 15.4 mm., 14.5 mm., 12.3 mm. and 14.6 mm. Broken specimens indicate that this species may attain a still larger size. One specimen would measure

27 mm. in width, 19.8 mm. in thickness and 36 mm. in length if restored.

Pedicle valve strongly arched from the beak to the front margin, with the greatest curvature posterior to the midlength, highest near the middle, the surface gently convex or flattened along the midline, sloping rapidly to the lateral and anterior margins, and strongly inflected to the posterolateral margins. Sinus nearly obsolete or appearing as an extremely shallow mesial depression confined to the anterior part of the valve or indicated there by a gentle flattening of the surface. Umbonal region prominent, broadly convex and projecting. Beak large, blunt, extended beyond the hinge line, incurved, and bearing apically a nearly circular foramen. Delthyrium large, broadly triangular, closed by two flat deltidial plates, which form a gently concave pseudoarea. Internally in the rostral part of the valve there are two short dental lamellae, which are divergent at their tops. Between and in some cases attached to them is a short tubular pedicle collar.

Brachial valve nearly as convex as the pedicle, strongly arched from beak to front, with the curvature increasing toward the beak, transversely flattened or gently convex in the central part, and strongly curved at the sides, the point of greatest convexity situated near the middle, the surface sloping strongly to the cardinal and lateral margins and less rapidly to the front. Mesial fold broad, originating at the midlength, flattened at the top, slightly elevated, poorly defined at the side, or indicated by the flattening of the median anterior part of the valve. Umbonal region moderately convex. Beak blunt and a little projecting. Internally the concave hinge plate is perforated beneath the beak and supported at the sides by the strong dental socket plates. The central part deepens and widens anteriorly as the sides thicken and give rise to the crural plates. The surface of both valves is marked by numerous concentric striae of growth, of which occasional ones are more pronounced.

Cranaena iowensis is somewhat variable but in general is distinguished by its subpentagonal shape, large size, nearly straight front margin, and its thick, almost gibbous shell. In the ephebic stages, the brachial valve is nearly circular, a little wider than long, and attains about half its mature length before becoming longer than wide.

Cranaena maxima Savage from the Cedar Valley beds near Rock Island, Ill., has not yet been recovered from Iowa. A number of specimens of *Cranaena iowensis* approach *Cranaena maxima* in size and may indicate that the latter is a large variety of the former. There are no apparent differences in shape.

Occurrence.—Cedar Valley limestone in the *Cranaena iowensis* zone, in which it is the most abundant and characteristic form. Randalia is the type locality, and good specimens still may be secured there. Others come from Lost Creek, Rapid Creek, Iowa City and Linder's Boathouse in Johnson County; and from exposures along the Mississippi in Scott and Muscatine Counties, Iowa.

Types.—Holotype, S.U.I. 6–217; idiotypes M.A.S. 57, 297 and 300.

CRANAENA SUBOVATA Savage

Plate 7, figures 6–8; text figure 9

Cranaena subovata SAVAGE, *1921*, Illinois Acad. Sci., vol. 14, no. 1, pp. 7, 8, pl. 2, figs. 9, 10.

Shell of medium size, elongate-ovate in shape, with the posterolateral margins long, nearly straight, and meeting posteriorly in an acute angle, the anterolateral margins short and nearly straight or broadly rounded; much longer than wide, broadest near or anterior to the midlength, usually strongly but subequally biconvex. Measurements of three hypotypes are: length of the pedicle valve 19.5 mm., 21.1 mm. and 27.4 mm.; width 14.3 mm., 15.7 mm. and 22 mm.; thickness 9.8 mm., 11.3 mm. and 13.7 mm.

Pedicle valve much the longer, strongly convex, arched from beak to front along the median line, with the curvature progressively greater posteriorly; surface sloping rapidly from the midpoint to the front and lateral margins, transversely flattened in the central part, compressed and inflected to the cardinal margins. Mesial sinus faint, broad, shallow, confined to the anterior part of the valve, obsolete, or indicated by a short lingual extension at the front. Umbonal region prominent, high, laterally compressed, and strongly extended beyond the hinge line. Beak large, pointed, and strongly projecting, displaying at the apex a large foramen. Del-

thyrium closed by deltidial plates, making a gently curved pseudoarea. Internally the dental plates are well developed and extend anteriorly about five millimeters. Between them is a short tubular pedicle collar. On the internal mold three or four long radiating furrows extend forward nearly to the margin.

Brachial valve nearly as convex as the pedicle, with the greatest convexity a little posterior to the middle, gently and regularly arched along the midline from the umbo to the front and more strongly to the beak; surface gently convex across the midline but sloping strongly to the lateral margins. Fold indistinct, originating near the midlength, widening to the front, broadly convex and but little elevated above the remainder of the valve. Umbo moderately convex. Beak small and a little projecting. Internally there is a transverse concave hinge plate connecting the dental sockets and perforated beneath the beak; anteriorly the central part of the hinge plate becomes deeper, the sides enlarging and forming the crural plates while the socket plates disappear; the crural plates become higher, larger, and more lamellose toward the front, while the concave portion becomes separate from the crural ridges and continues a short way anteriorly. Concentric growth lines are common on both valves.

Our specimens are considerably larger than the specimens on which Savage bases his description but agree in other features. Small examples seem to be identical. Savage notes that the average size of *Cranaena iowensis* is smaller at his Illinois locality also.

This species is easily separated from the other Cranaenas of the Cedar Valley beds. *Cranaena subovata* is differently shaped, being more ovate in outline than *Cranaena iowensis*, narrower and more elongate in the posterior part of the shell, has the greatest width more anterior, and the anterolateral margins rounded.

Occurrence.—Cedar Valley limestone in the *Cranaena iowensis* zone. At same localities as *C. iowensis*.

Types.—Holotype, University of Illinois; hypotypes, S.U.I. 6–397 to 6–399, 6–402 to 6–404, M.A.S. 160; idiotypes M.A.S. 246.

CRANAENA LATA Stainbrook, n. sp.

Plate 7, figures 16–20; plate 8, figures 4–6; text figure 1

Shell of medium size, subequally biconvex, subtriangular in outline, with rounded anterolateral margins and acute posterior angle, a little longer than wide, with the greatest width anterior to the midlength. Anterior commissure not sinuate. Measurements of the holotype and of two paratypes are: length 22.1 mm., 17.5 mm. and 22.2 mm.; width 21.5 mm., 16.6 mm. and 21.4 mm.; thickness 13.6 mm., 10.1 mm. and 12.9 mm.

Pedicle valve arching strongly and regularly from beak to front but with slightly increasing curvature over the umbo, highest posterior to the midpoint, whence the surface descends strongly and evenly to the front and anterolateral margins. Umbonal region high, prominent, and with the sides strongly inflected to the hinge line. Beak strong, acute, projecting, slightly incurved, bearing a large circular to oblong foramen at the apex.

Brachial valve less convex than the pedicle, a little wider than long, highest in the umbonal region; surface curving with equal rapidity to the front and lateral margins, more strongly to the posterior, slightly flattened mesially at the front. Umbo high, broadly convex; beak pointed and projecting.

Shell abundantly punctate. Exterior smooth but occasionally wrinkled slightly by strong growth lines. Several examples show areas of varying color radiating from the beaks. Internal characteristics are shown in text figure 1.

Cranaena lata differs from *Cranaena iowensis* in shape, being subtriangular instead of subovate, has the width and length more nearly equal, has a more acute posterior, rounded anterolateral margins, a nonsinuate front commissure, and the greatest width is more anterior. Its distinct shape separates it readily from other members of the genus approaching it in size.

Occurrence.—Cedar Valley limestone in the *Cranaena iowensis* zone at Randalia and Iowa City, Iowa.

Types.—Holotype, M.A.S. 787; paratypes, M.A.S. 298 and 788.

CRANAENA SUBLINGULATA
Stainbrook, n. sp.
Plate 7, figures 11–13, 30; text figure 2

Shell above medium size, moderately biconvex, elongate subpentagonal in outline, with long nearly straight posterolateral margins, shorter and slightly curved anterolateral margins, and short truncate front margin; broadest anterior to the midlength, slightly sinuate or straight along the anterior commissure. Measurements of the holotype and of a paratype are: length 21 mm. and 25.2 mm.; 19.5 mm. and 22.8 mm.; width 15.4 mm. and 13.6 mm.; thickness 9.8 mm. and 13.5 mm.

Pedicle valve the more convex, arching strongly and regularly from the front to the beak, with increasing curvature over the umbo, strongly arched transversely in the posterior part, but with decreasing curvature anteriorly; median part slightly flattened and projecting at the front. Umbo moderately elevated, narrow; beak pointed, projecting, narrow, slightly incurved.

Brachial valve most convex in the umbonal region, whence the surface curves with moderate rapidity to the front margin and more rapidly to the lateral margins, strongly arched transversely in the posterior half, less arched anteriorly. Anterior median part a little elevated and flattened. Beak small, pointed, projecting beyond the hinge line.

Shell substance abundantly and minutely punctate. Growth lines numerous, some may be more prominently developed. The internal structures are shown in text figure 2. Comparison with the diagram of *Cranaena iowensis* (text figure 8) shows that there are differences in the shape of the loop.

Cranaena sublingulata is near *Cranaena subovata* but is more elongate and pointed posteriorly, proportionately narrower, and thinner, its greatest width is nearer the midlength, and its anterolateral margins are nearly straight and not broadly rounded. It is proportionately broader than *Cranaena subcylindrica*, thinner, its posterior end is broader and less extended, its beak is straighter and its anterolateral margins are nearly straight instead of curved.

Occurrence.—Cedar Valley limestone in the *Cranaena iowensis* zone in Muscatine and Scott Counties, Iowa.

Types.—Holotype S.U.I. 6–402; paratypes, S.U.A. 6–403, 6–404, 6–397 to 6–399.

CRANAENA SUBGLOBOSA Stainbrook, n. sp.
Plate 8, figures 17–26; text figure 3

Shell small, subequally biconvex, subpentagonal to subtriangular in outline, with rounded anterolateral margins, nearly straight posterolateral margins, and slightly truncate front margin; a little longer than wide, with the greatest width anterior to the midlength. Anterior commissure gently sinuate. Dimensions of the holotype and of three paratypes are: length of the pedicle valve 12.7 mm., 12.8 mm., 13.3 mm. and 11.2 mm.; length of the brachial valve 10.8 mm., 10.9 mm., 11.3 mm., and 9.1 mm.; width 11.1 mm., 10.8 mm., 10.1 mm. and 9.7 mm.; thickness 9.3 mm., 9.1 mm., 9.1 mm. and 8.1 mm.

Pedicle valve more convex than the brachial, regularly and strongly arched from beak to front, with the curvature increasing over the umbo, the point of greatest convexity situated near the middle, the surface sloping rapidly to the anterior and lateral margins, strongly to the posterior, and becoming inflected near the hinge line. Median sinus shallow, gently rounded at the bottom, extending only a short way posteriorly from the front margin, nearly obsolete in some specimens or indicated by a gentle mesial flattening on the anterior mesial portion of the valve. Umbonal region strongly elevated, projecting a short distance beyond the hinge line. Beak short, pointed, incurved, a little extended, displaying a small subcircular foramen. Internally the dental lamellae are strongly developed in the rostral part of the valves and extend a short way anteriorly. The internal mold shows several grooves radiating from the beak and nearly reaching the front of the valve.

Brachial valve about as wide as long, evenly arched, with moderate curvature along the midline, highest near the midpoint, the surface sloping thence with moderate rapidity to the front and lateral margins and more rapidly to the hinge line, transversely flattened along the midline from the umbo to the front, where there is little or no indication of a fold. Umbonal region broadly convex, not extended poste-

riorly. Beak blunt, slightly projecting. Internal characters are shown in the accompanying diagram.

Surface of both valves marked by a few fine concentric growth lines, of which occasional ones may be more strongly developed. Gerontic individuals tend to be long, more extended posteriorly, and have the greatest width farther forward. Immature specimens are more subtriangular in shape, proportionately broader, with a more obtuse angle formed by the posterolateral margins.

Cranaena subglobosa is the form which Cooper and Cloud[1] have recently stated is conspecific with *Cranaena romingeri* of the Partridge Point shale of Thunder Bay, Michigan, and of the Devonian of Calhoun County, Illinois. Comparison of specimens of *Cranaena subglobosa* with *Cranaena romingeri* from each of those localities shows that there are some persistent differences. *Cranaena subglobosa* is larger, more robust, and less extended posteriorly. Specimens of *Cranaena subglobosa* of the same length as *Cranaena romingeri* are more nearly triangular, less ovate, blunter posteriorly, and broader, with the greatest width nearer the front. Immature individuals of both species are even more unlike.

Cranaena romingeri occurs also in the Cedar Valley but in the *profunda* zone as described below and not in the *Cranaena iowensis* zone. On the other hand *Cranaena subglobosa* is represented in the *profunda* zone but by individuals which are not to be confused with *Cranaena romingeri.*

Cranaena subglobosa is smaller than *Cranaena elliptica* Savage, has a distinct sinus in the pedicle valve, and is broadest anterior to the midlength.

Occurrence.—Cedar Valley limestone, abundantly in the *Cranaena iowensis* zone at Iowa City, Robert's Ferry, Lost Creek and Mid River in Johnson County, Iowa; sparingly in the *profunda* zone at Brandon and elsewhere.

Types.—Holotype, S.U.I. 6–219A, paratypes, S.U.I. 6–219, 6–220, 6–386, M.A.S. 252, 317, 318, 47.

Cranaena littletonensis
Stainbrook, n. sp.
Plate 8, figures 39–44; text figure 4

Shell small to medium-sized, elongate subovate, subequally biconvex, longer than wide, with the greatest width at the midlength. Measurements of the holotype and of a paratype are: length of pedicle valve 15.8 mm. and 13.6 mm.; length of brachial valve 14.1 mm. and 12.9 mm.; width 13.5 mm. and 11.8 mm.; thickness 8.1 mm. and 6.9 mm. A crushed specimen indicates that a length of 20 mm. may be attained.

Pedicle valve moderately convex, regularly arched from the beak to the front margin, with the greatest convexity in the umbonal region; surface gently convex and a

[1] *1938, Jour. Paleontology,* vol. 12, no. 5, p. 499.

Explanation of Plate 7

Figs. *1–5, 25—Cranaena iowensis* (Calvin). *1–4,* Pedicle, brachial, anterior and lateral views of the holotype, (S.U.I. 6–217), Randalia, Iowa. *5,* Brachial view of a large example comparable with *Cranaena maxima* Savage. *25,* Pedicle view of a large example showing median fold. (p. 44)

6–8—Cranaena subovata Savage. Pedicle, brachial and lateral views of an example from Iowa City which was compared with the type (M.A.S. 246 A). (p. 45)

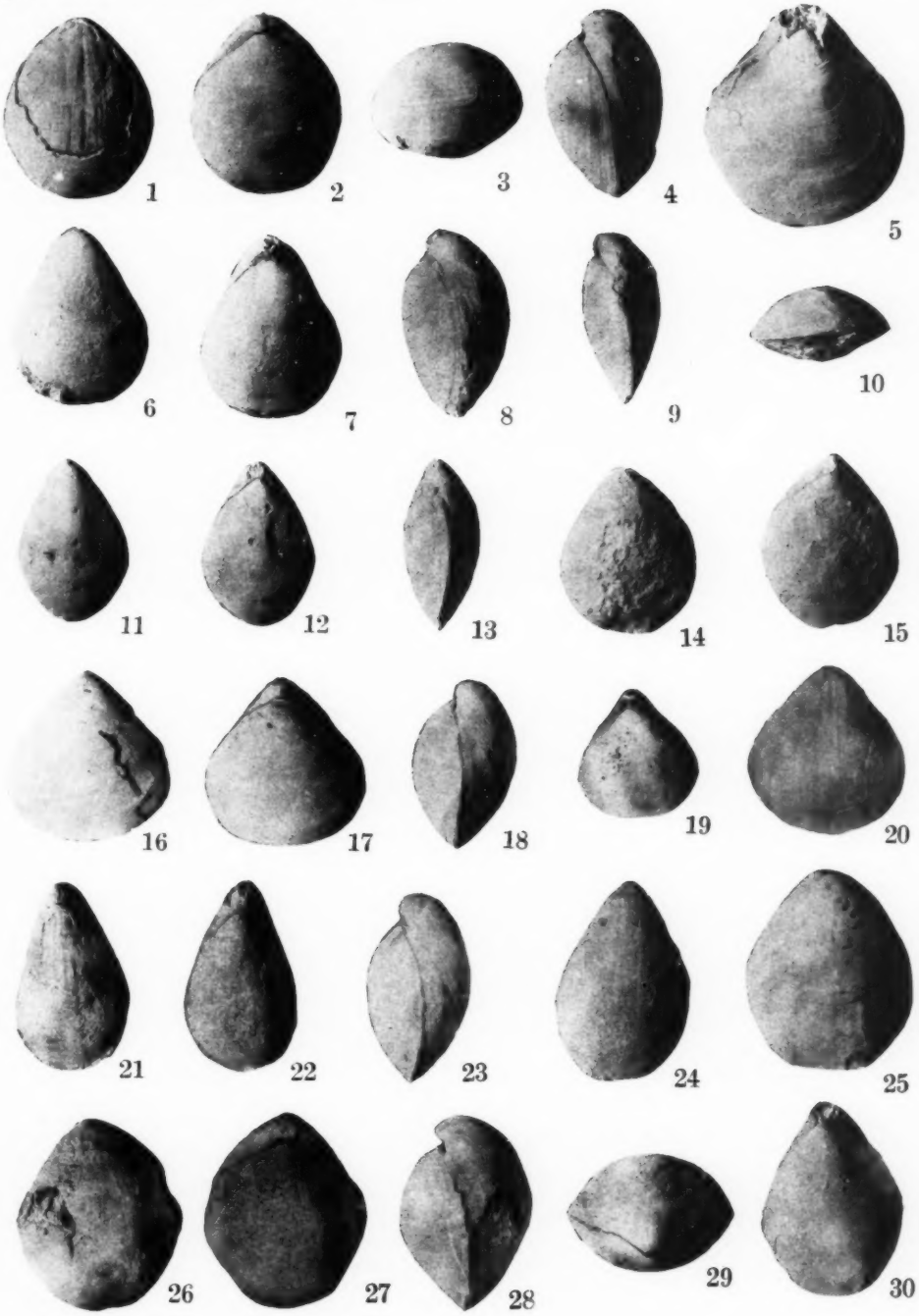
9, 10, 14, 15—Cranaena thomasi Stainbrook, n. sp. Lateral, anterior, pedicle and brachial views of the holotype (M.A.S. 51), Independence, Iowa. (p. 54)

11–13, 30—Cranaena sublingulata Stainbrook, n. sp. *11–13,* Pedicle, brachial and lateral views of the holotype (S.U.I. 6 402). *30,* Brachial view of a paratype (S.U.I. 6-403). Both from Muscatine County, Iowa. (p. 47)

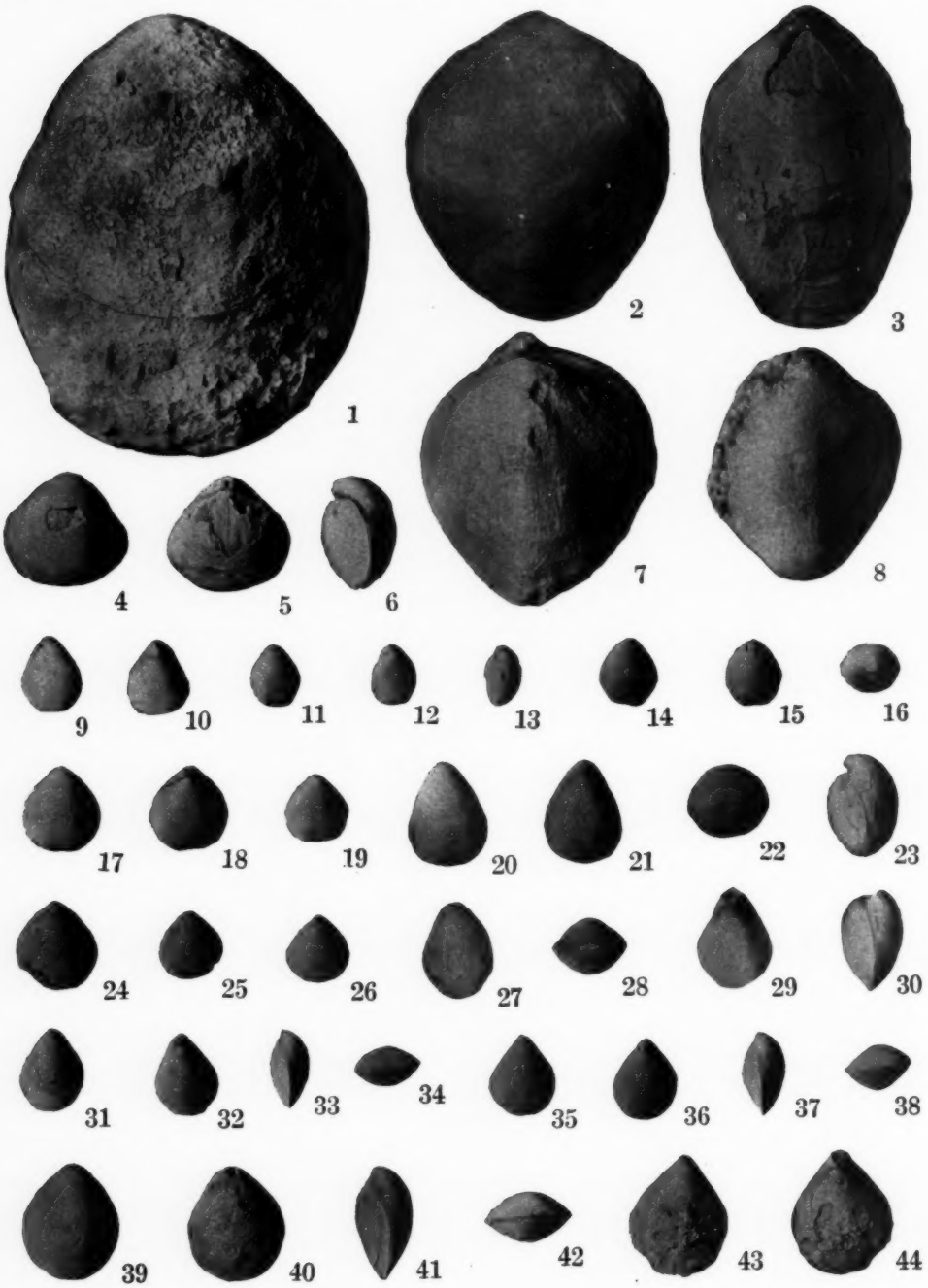
16–20—Cranaena lata Stainbrook, n. sp. *16–18,* Pedicle, brachial and lateral views of the holotype (M.A.S. 787 A). *19,* Brachial views of a medium-sized paratype (M.A.S. 787). *20,* Pedicle view of another partially decorticated paratype (M.A.S. 298). Both from Randalia, Iowa. (p. 46)

21–24—Cranaena subcylindrica Cooper and Cloud. *21–23,* Pedicle, brachial and lateral views of a hypotype (Belanski Coll. 6810). *24,* Pedicle view of a decorticated specimen (Belanski Coll. 6790). Both from the *profunda* zone in Johnson County, Iowa. (p. 54)

26–29—Cranaena inflata Stainbrook, n. sp. Pedicle, brachial, lateral and posterior view of the holotype (S.U.I. 6–215), *bellula* zone, Brandon, Iowa. (p. 49)



Stainbrook, Devonian Brachiopods



Stainbrook, Devonian Brachiopods

little elevated along the midline, sloping with moderate rapidity thence to the anterolateral margins, more rapidly to the posterolateral margins, and becoming inflected beneath the beak. Umbonal region broadly convex and but little extended. Beak short, blunt, incurved, and slightly projecting. Two short dental lamellae are visible beneath the shell of the beak, and a short pedicle collar appears between them.

Brachial valve less convex than the pedicle, gently and evenly arched along the median line from the beak to the anterior margin, highest near the middle, the surface sloping thence with moderate rapidity to the margins. Umbonal region low and broadly convex, and but little elevated. Beak short, blunt, scarcely projecting. Internal characters of the shell are illustrated in text figure 4.

The surface of the valves is marked by numerous fine concentric growth lines, of which several on each valve may be pronounced. The shell substance is finely punctate. A characteristic feature of this species is the preservation of color markings; of the 50 specimens at hand nearly half show bands and patches of reddish brown. The color usually appears as four to six longitudinal stripes radiating from the beaks and widening toward the front. They are developed equally well on both valves and seem to be on the inner surface of the shell. Internal molds often show the bands after the shell has been removed.

The small size and distinct color markings separate this from the larger species. It is larger than *Cranaena elia* and less pointed posteriorly. The specimens illustrated by Cleland, (Wisconsin Geol. Survey, Bull. 21 pl. 13, figs. 8, 9) bear considerable resemblance to this form.

Occurrence.—Cedar Valley in the *waterlooensis* zone at Littleton, Brandon, and Randalia.

Types.—Holotype S.U.I. 6–391; paratypes S.U.I. 6–392 to 6–395 and M.A.S. 128, 248, 1248, and 1249.

CRANAENA INFLATA Stainbrook, n. sp.
Plate 7, figures 26–29; text figure 6

Shell above medium size, strongly biconvex, longer than wide, broadest at the midlength, subovate to subpentagonal in out-

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EXPLANATION OF PLATE 8

FIGS. *1*—*Rensselandia missouriensis* (Swallow). Pedicle view (S.U.I. 6-435), Fairbanks, Iowa. (p. 44)

2, 7, 8—*Rensselandia cordiforme* Stainbrook, n. sp. *2*, Pedicle view of the holotype (M.A.S. 1251), Vinton, Iowa. *7*, Brachial view of a paratype (S.U.I. 6-436). *8*, Pedicle view of another paratype (S.U.I. 6-436). (p. 43)

3—*Rensselandia johanni* Hall. Brachial view of a speciman (S.U.I. 6-502), Brandon, Iowa. (p. 43)

4–6—*Cranaena lata* Stainbrook, n. sp. Pedicle, brachial and lateral views of a medium-sized example (S.U.I. 6-214), Littleton, Iowa. (p. 46)

9–16—*Cranaena romingeri* Hall. *9–10*, Pedicle and brachial views respectively of two examples from Partridge Point, Mich. *11–13*, Pedicle, brachial and lateral views of a hypotype. *14–16*, Pedicle, brachial, and anterior views of another hypotype. Both from the *profunda* zone at Linn Junction, Iowa (M.A.S. 89). (p. 51)

17–26—*Cranaena subglobosa* Stainbrook, n. sp. *17, 18*, Pedicle and brachial views of the holotype (S.U.I. 6-219), Iowa City, Iowa. *19*, Pedicle view of a small paratype. *20–23*, Pedicle, brachial, anterior and lateral views of a large specimen showing gerontic characters (S.U.I. 6-218), Robert's Ferry in Johnson County, Iowa. *24*, Pedicle view of a specimen. *25, 26*, Pedicle and brachial views of another. Both from the *profunda* zone at Brandon, Iowa (M.A.S. 47). (p. 47)

27–30—*Cranaena arcuosa* Stainbrook, n. sp. *27, 28*, Pedicle and anterior views of the holotype (M.A.S. 58). *29, 30*, Brachial and lateral views of a paratype. Both from the *profunda* zone, near Linn Junction, Iowa. (p. 53)

31–34—*Cranaena jucunda* Hall. Pedicle, brachial, lateral and anterior views of a hypotype (S.U.I. 6-221), Brandon, Iowa. (p. 53)

35–38—*Cranaena elia* Hall. Pedicle, brachial, lateral and anterior views of a hypotype (S.U.I. 6-223), Vinton, Iowa. (p. 52)

39–44—*Cranaena littletonensis* Stainbrook, n. sp. *39–42*, Pedicle, brachial, lateral and anterior views of the holotype (S.U.I. 6-391), Littleton, Iowa. *43, 44*, Pedicle and brachial views, of a paratype (M.A.S. 248), Randalia, Iowa. (p. 48)

1, Cranaena lata Stainbrook, n. sp., x 1

2, Cranaena sublingulata Stainbrook, n. sp., x 2½

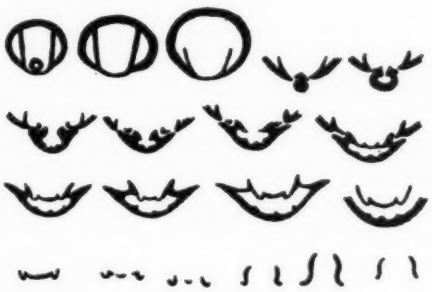
3, Cranaena subglobosa Stainbrook, n. sp., x 2½

4, Cranaena littletonensis Stainbrook, n. sp., x 2½

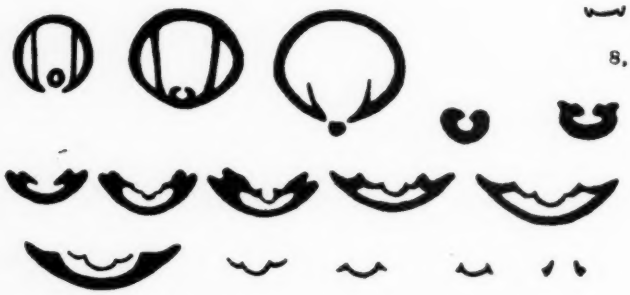
5, Cranaena romingeri Hall, x 2½

6, Cranaena inflata Stainbrook, n. sp., x 1½

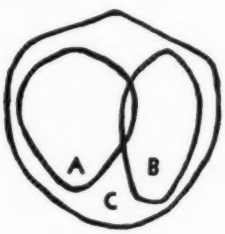
7, Cranaena arcuosa Stainbrook, n. sp., x 2½



8, Cranaena iowensis (Calvin), x 1



9, Cranaena subovata Savage, x 2½



10, Rensselandia, x ½

FIGS. 1–10.—Cross sections of *Cranaena* and outlines of *Rensselandia*. For detailed explanation see opposite page.

line, with nearly straight front and anterolateral margins. Anterior commissure gently sinuous. Dimensions of the holotype, a nearly perfect specimen, are: length 25.1 mm.; width 22.1 mm.; thickness 17.6 mm. An incomplete specimen lacking the anterior one-third measures 22.7 mm. in width and 15.8 mm. in thickness. Another incomplete but uncrushed specimen 27.2 mm. in width indicates that larger dimensions may be attained.

Pedicle valve strongly arched from beak to front, most convex a little posterior to the midlength, the surface gently elevated and flattened along the midline and sloping with moderate rapidity beyond to the lateral margins, strongly incurved beneath the beak, and flattened near the cardinal margins into a small pseudoarea. Beak strongly developed, projecting and incurved beyond the opposite beak, pierced by a large foramen; beak ridges distinct, almost angular.

Brachial valve strongly convex, highest a little posterior to the midlength, flattened slightly toward the anterior margins and along the midline toward the front, gently elevated in the umbonal region. Beak small, scarcely projecting.

Posteriorly both valves show six or more lines of darker material radiating from the beaks, widening toward the front, and disappearing near the middle of the shell. Concentric growth lines are more numerous on the anterior parts of the valves. The earliest lines of increment show the shell in the earlier stages to have been as wide as long or broader, the length becoming greater than the width in the adult stages.

Cranaena inflata is larger and more strongly biconvex than *Cranaena thomasi* and its brachial valve is more nearly circular. *Cranaena inflata* is shorter and considerably thicker than *Cranaena iowensis* in proportion to size. It differs also in having a more strongly incurved beak, a higher umbo, and a more nearly circular and more strongly inflated brachial valve.

Occurrence.—Cedar Valley limestone: *bellula* zone at Shellsburg, Brandon, Rapid Creek and Linder's Boathouse in Johnson County.

Types.—Holotype, S.U.I. 6–215; paratypes 147, 457.

CRANAENA ROMINGERI Hall

Plate 8, figures 9–16; text figure 5

Terebratula roemingeri HALL, *1863*, New York State Lab. Nat. History, 16th Ann. Report, p. 48, figs. 22, 23.

Terebratula roemingeri HALL, *1867*, Paleontology New York, vol. 4, p. 389, pl. 60, figs. 17–25, 66, 67.

Cranaena romingeri HALL and CLARKE, *1893*, *idem*, vol. 8, pt. 2, p. 297, pl. 80, figs. 13–19.

EXPLANATION OF TEXT FIGURES 1–10

FIG. *1*—*Cranaena lata* Stainbrook, n. sp. A series of cross sections of the rostral part of a paratype. The first four are of the pedicle valve; the remainder show the brachial valve or the loop. (p. 40)

2—*Cranaena sublingulata* Stainbrook, n. sp. Serial sections of the rostral part of a paratype. The first shows the structures of the pedicle valve; the remainder are of the brachial valve or the loop. (p. 47)

3—*Cranaena subglobosa* Stainbrook, n. sp. Serial sections of the posterior part of a paratype. The first five show the pedicle valve; the remainder figure the brachial valve or the loop. (p. 47)

4—*Cranaena littletonensis* Stainbrook, n. sp. Serial sections of the rostral part of a paratype. The last two are of the brachial valve only. (p. 48)

5—*Cranaena romingeri* Hall. Serial sections of a specimen from the *profunda* beds of Iowa. The first row shows the pedicle valve; the remainder are of the brachial valve. (p. 51)

6—*Cranaena inflata* Stainbrook, n. sp. Serial sections of the posterior half of a paratype. The pedicle valve is shown in the first three, the brachial valve in the remainder. (p. 49)

7—*Cranaena arcuosa* Stainbrook, n. sp. Serial sections of the rostral part of a paratype. The upper row is of the pedicle valve; the lower row shows the brachial valve and the loop. (p. 53)

8—*Cranaena iowensis* (Calvin). Serial sections of the rostral part of a specimen from Randalia, Iowa. The pedicle valve appears in the first three sections, partly in the second row. In the lowest row only the loop is shown. (p. 44)

9—*Cranaena subovata* Savage. The first three sections show the pedicle valve; the remainder are of the brachial valve or the loop. (p. 45)

10—Outlines of three species of *Renssellandia*. A, *R. cordiforme* Stainbrook, n. sp.; B, *R. johanni* Hall; C, *R. missouriensis* (Swallow). The last is from a specimen figured by Branson in the Devonian of Missouri. (p. 43)

Cranaena romingeri BELANSKI, *1928*, Iowa Univ. Studies in Nat. History, vol. 12, no. 8, pp. 5–7, pl. 1, figs. 12–17, not figs. 9–11.

Shell small, strongly biconvex, longer than wide, with the greatest width at the midlength, subpentagonal in outline, with the posterolateral margins gently rounded and forming an acute angle at the beak, the anterolateral margins nearly straight, and the front margin truncate. Anterior commissure gently unisinuate. Measurements of two hypotypes are: length 8.5 mm. and 8.3 mm.; width 7.8 mm. and 6.8 mm.; thickness 6.5 mm. and 6 mm.

Pedicle valve strongly and evenly arched from beak to front but more strongly arched transversely; surface gently convex in the central part, abruptly curved at the sides to the lateral margins and inflected to the cardinal margins. Sinus originating at the midlength and extending to the anterior margin as a narrow shallow depression, rounded at the bottom; in some specimens it may be nearly obsolete. Umbonal region prominent, elevated, and extended beyond the hinge line. Beak strong, sharply pointed, incurved over that of the opposite valve, and bearing a small circular foramen. Internally two short, stout dental lamellae are present in the rostral part of the valve. They are divergent at their tops and extend anteriorly a short distance. Between them is a short pedicle collar.

Brachial valve much shorter and less convex than the pedicle, strongly arched from beak to front and from side to side, highest at the middle, gently convex centrally, sloping sharply near the margins, gently flattened in the anterior mesial portion. Umbonal region convex; beak small, blunt, and but little extended. Internally the structure is similar to that of other members of the genus and is shown in text figure 5.

The small size, the shape, and the thickness of the shell readily separate it from other species of *Cranaena* in the Cedar Valley beds. Present known occurrences indicate that this species is more widespread than other brachiopods in this formation. Our examples average a little smaller than specimens from the type locality in Michigan and may be slightly thicker proportionately. They agree dimensionally with examples from Calhoun County, Illinois.

Occurrence.—Cedar Valley limestone in the *profunda* zone at Linn Junction, Vinton and Brandon, Iowa. In beds equivalent to the Cedar Valley in Calhoun County, Illinois, in the same relative zone. Originally described from Michigan.

Types.—Hypotypes, M.A.S. 59, 434 and S.U.I. 6–388.

CRANAENA ELIA (Hall)
Plate 8, figures 35–38

Terebratula elia HALL, *1867*, Paleontology New York, vol. 4, p. 390, pl. 60, figs. 26–28.
Terebratula elia SCHUCHERT, *1897*, U. S. Geol. Survey, Bull. 87, p. 445.

Shell small, subequally biconvex, elongate oval in shape, longer than wide, with the greatest width near the midlength. Measurements of two hypotypes are: length 11.6 mm. and 11 mm.; width 8.5 mm. and 8.5 mm.; thickness 5 mm. and 5.7 mm.

Pedicle valve strongly arched from beak to the front margin, with the curvature becoming progressively greater posterior to the midlength; surface sloping strongly and regularly from the umbo to the anterior and lateral margins, abruptly inflected to the cardinal margins, gently convex transversely along the midline, and flattened a little anteriorly. Umbonal region strongly convex, projecting. Beak strong, pointed, extended, incurved, bearing a subcircular foramen at the apex. Two short dental lamellae appear beneath the shell of the beak.

Brachial valve less convex than the pedicle, gently arched from the beak to the anterior margin, with the greatest convexity in the umbonal region, the surface sloping evenly and gently to the front and lateral margins and more rapidly on either side of the beak to the cardinal margins; transversely the surface is slightly elevated and gently convex along the median line. Beak small, pointed and projecting.

Surface of both valves marked by a few fine concentric lines of increment. Shell substance abundantly punctate. Beneath the shell of both valves of a hypotype are visible six color bands of reddish brown radiating from the beaks and increasing in width toward the front. Where the shell is exfoliated the internal mold is colored similarly.

The small size will distinguish this form from the larger Cranaenas. From *Cranaena*

littletonensis it differs in having the pedicle valve more extended and narrowed toward the beak. The specimens at hand are too few to permit sectioning, but the presence of dental lamellae and the external resemblance to known species of *Cranaena* makes reference to this genus probable. The hypotypes were compared with the holotype and found to be identical. *Cranaena radiata* Cooper and Cloud from Calhoun County, Illinois, appears to be similar to *Cranaena elia*, but comparison of actual specimens must be made before the two species can be said to be identical.

Occurrence.—Cedar Valley in the *profunda* zone at Waterloo, Brandon, and Vinton.

Types.—The holotype is in the American Museum of Natural History; hypotypes, S.U.I. 6–221 and 6–223.

CRANAENA JUCUNDA (Hall)
Plate 8, figures 31–34

Terebratula jucunda HALL, *1867*, Paleontology New York, vol. 4, p. 390, pl. 60, figs. 29–31.
Terebratula jucunda SCHUCHERT, *1897*, U. S. Geol. Survey, Bull. 87, p. 446.

Shell small, subovate in outline, a little longer than wide, with the greatest width anterior to the middle. A hypotype measures 7.5 mm. in length, 7 mm. in width and 4 mm. in thickness.

Pedicle valve more convex than the brachial, the greatest convexity posterior to the midlength, the surface sloping with moderate rapidity from the umbo to the front and lateral margins, more rapidly toward the hinge line and a little incurved beneath the beak. Umbonal region strongly arched transversely, projecting; beak short, pointed, and incurved, pierced by a small apical foramen. Internally two short dental lamellae are visible beneath the shell of the rostral portion of the valve.

Brachial valve nearly circular in outline, gently arched from beak to front and from side to side, slightly more convex in the posterior half. Umbo low; beak small, pointed, a little extended. Internal structure unknown. Numerous fine concentric growth striae marked the surface of both valves. Shell substance shows numerous punctae.

The specimens on which the above description is based were compared with the holotype and found to be the same. It is thought that this species belongs to the genus *Cranaena* but this reference cannot be settled definitely until more specimens have been sectioned.

Cranaena jucunda differs from *Cranaena elia*, with which it is associated, in that it is shorter in proportion to length, the posterior part of its pedicle valve is much less extended, and its brachial valve is more nearly circular. It is broader and thinner than *Cranaena romingeri* of the same horizon.

Occurrence.—Cedar Valley in the *profunda* zone at Waterloo, Brandon, and Vinton.

Types.—Hypotypes, M.A.S. 303.

CRANAENA ARCUOSA Stainbrook n. sp.
Plate 8, figures 27–30; text figure 7

Shell below medium size, strongly biconvex, elongate-ovate in outline, with the posterolateral margins long and meeting in an acute angle at the beak, longer than wide, broadest a little anterior to the midlength. Dimensions of the holotype and of a paratype are: length 14.5 mm. and 13.8 mm., width 10.3 mm. and 10.5 mm.; thickness 7.8 mm. and 10.5 mm.

Pedicle valve strongly arched from beak to front, with the greatest convexity posterior to the midlength; strongly arched transversely in the posterior portion and moderately so toward the front; surface sloping rapidly from the midline to the anterolateral margins, abruptly to the posterolateral margins, and broadly incurved beneath the beak. Mesial sinus obsolete or rarely indicated in some specimens by a slight flattening of the anterior median part of the valve. Umbonal region highly convex and elevated, considerably extended beyond the hinge line. Beak strong, pointed, incurved, projecting, and bearing a moderately large subcircular foramen. Internally in the rostral part of the valve there are two thin dental septa, which diverge at the top and enclose a short pedicle collar.

Brachial valve less convex than the pedicle, strongly and regularly curved along the midline, with the curvature greatest in the umbonal region; strongly arched transversely in the posterior half of the valve and gently so anteriorly; the surface curving strongly from the umbo to the front and lateral margins and abruptly to the hinge

line, mesially flattened near the front margin in some specimens. Umbonal region broadly convex; beak broad, blunt and but little extended. Internally the curved hinge plate is perforated posteriorly and extends a short way toward the front. Surface of both valves marked by numerous fine concentric lines of increment, usually more numerous toward the anterior margin. Shell substance minutely punctate.

This species is readily separated from *Cranaena romingeri* by its larger, more extended umbonal region in the pedicle valve, and the general lack of a distinct pedicle sinus. It is larger and differently shaped. It is more extended in the posterior region, thicker than *Craneana elia* and *Cranaena jucunda*, and differently shaped. It is more extended in the posterior region and thicker than *Cranaena littletonensis*.

Cranaena arcuosa is proportionately thinner, longer and narrower than *Cranaena myriopunctata* Cooper and Cloud, and less rounded anteriorly. *Cranaena arcuosa* resembles *Cranaena amygdaloidea* but differs in being thicker, larger, in having a narrower and more extended pedicle beak, and in being widest anterior to the midlength.

Occurrence.—Cedar Valley limestone in the *profunda* zone at Linn Junction and Vinton.

Types.—Holotype, M.A.S. 58; paratypes 322.

CRANAENA SUBCYLINDRICA
Cooper and Cloud
Plate 7, figures 21–24

Cranaena subcylindrica COOPER and CLOUD, *1938*, Jour. Paleontology, vol. 12, no. 5, p. 448, pl. 54, figs. 48, 49.

Shell above medium size, strongly and subequally biconvex, elongate-ovate in outline, with broadly rounded anterolateral margins and long, nearly straight posterolateral margins forming an acute angle, broadest posterior to the midlength, and anterior margin gently sinuous along the anterior commissure. Measurements of two hypotypes are: length 24.7 mm. and 25.9 mm.; length of the brachial valve 20.8 mm. and 22.3 mm.; width 15.1 and 17.3 mm.; thickness 14.1 mm. and 12.4 mm.

Pedicle valve more convex than the brachial, highest at the midpoint, strongly arched transversely in the posterior half, less so toward the front, flattened a little mesially near the anterior margin. Umbo high, narrow, with nearly flat sides at right angles to the plane of the valves. Beak long, pointed, narrow, incurved, and extended considerably beyond the hinge line. Two short septa are present in the beak.

Brachial valve highest posterior to the midpoint, arching strongly and regularly from front to back but with increasing curvature over the umbo, strongly arched transversely in the posterior part and decreasingly so toward the front. Umbo high; beak pointed and projecting. Surface of both valves marked by numerous lines of growth, some of which may be strongly impressed on the internal mold.

Cranaena subcylindrica is narrower than *Cranaena subovata*, has a more extended and narrower posterior and a more acutely angular beak. The same characters also separate it from *Cranaena iowensis*. No example from the type locality is at hand, but our specimens were compared with plaster reproductions of the holotype.

Occurrence.—Cedar Valley limestone in the *profunda* zone in Johnson County, and near Troy Mills and Shellsburg, Iowa. Originally described from the basal part of a limestone, equivalent to the Cedar Valley in Calhoun County, Illinois.

Types.—Holotype. U. S. Nat. Mus. 95174. Hypotypes, M.A.S. 1250; Belanski collection 6790, 6810; S.U.I. 6–216.

CRANAENA THOMASI Stainbrook n. sp.
Plate 7, figures 9, 10, 14, 15

Shell of medium size, moderately but inequally biconvex, oval in outline, longer than wide, with the greatest width at or near the midlength, thin, gently sinuous along the front commissure. The holotype and a paratype measure 22.8 mm. and 16.3 mm. in length, 18.7 mm. and 12.8 mm. in width and 10 mm. and 7.6 mm. in thickness.

Pedicle valve more convex than the brachial, with the greatest convexity posterior to the midlength; strongly arched from the beak to the front margin and less strongly from side to side, the surface sloping with even gentle curvature from the umbo to the front and lateral margins and curving

strongly and inwardly beneath the beak to the hinge line. Sinus broad, extremely shallow, confined to the median anterior part of the valve. Umbonal region prominent and extended beyond the hinge line. Beak strong, pointed, projecting and incurving, bearing at the apex a small circular foramen, which is directed outward at right angles to the plane of the valve. False cardinal area small and gently concave. Two short dental lamellae are visible beneath the shell of the rostral part of the beak.

Brachial valve gently arched from beak to front, with the point of greatest convexity at the middle; more strongly arched transversely, the surface gently convex and a little elevated along the midline and curving thence with moderate rapidity to the lateral margins. Fold low, scarcely elevated, originating in front of the umbo and expanding toward the front, depressed and poorly defined at the sides by gentle flexures. Umbonal region gently convex. Beak small, blunt, and but little projecting. Interior unknown. Surface of both valves marked by numerous concentric growth lines. Shell substance abundantly punctate.

The specimens at hand are too few to section, but the external characteristics seem sufficient to warrant provisional reference to the genus *Cranaena*. It is similar in outline to *Cranaena iowensis* but is much thinner, the brachial valve is less convex and proportionately longer, and the front margin is rounded instead of straight. From *Cranaena subovata* it differs in being broader in proportion to length and its greatest width is more posterior.

Occurrence.—Cedar Valley limestone in the *independensis* zone at Independence and Solon.

Types.—Holotype, M.A.S. 251; paratype, 196.

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JOURNAL OF PALEONTOLOGY, VOL. 15, NO. 1, PP. 56–60, 5 TEXT FIGS., JANUARY, 1941

PLIOCYON WALKERAE, A NEW PLIOCENE CANID FROM TEXAS

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THE SKULL and lower jaws of the canid described in this paper are part of a collection obtained for the West Texas State College from a quarry on the Adam Rizley ranch 1¾ miles southeast of Goldston, Texas. The excavation was done in the early part of the summer of 1938 through the coöperation of the Work Projects Administration and Donley County under the supervision of the junior author. Assistance in the preparation of the data presented in this paper was furnished by the personnel of the Work Projects Administration on official project number 65–66–7837. The paper was completed after the death of the senior author.

The strata are for the most part alternating shales and fine sands. The beds immediately above the fossil-bearing stratum of buff sand are shales, clay, sand, and small quantities of gravel. The stratum overlying the fossil zone is a sandy shale. The pebbles and sand grains are rounded, and the deposit is cross-bedded, showing that the sediments are of fluvial origin. Equidae, Camelidae, Antilocapridae, *Testudo*, Canidae, and other unidentified carnivores are abundant in this quarry in the order listed. The bones are well preserved, and few specimens show signs of being waterworn. Fragmentary material is scarce.

The complete skull and lower jaws described here constitute the only remains of *Pliocyon walkerae*, n. sp., thus far discovered. There is almost no distortion of the skull, and the only parts missing are a few fragments of the lambdoidal and sagittal crests and I_2 I_3 ? on both premaxillae. The lower jaws are complete with the exception of the tips of the coronoid processes. The first premolar on the right side, the third molar on the left, and the incisors are missing. The teeth are but slightly worn.

PLIOCYON WALKERAE
Johnston and Christian, n. sp.
Text figures 1–5

Etymology.—The specific name *walkerae* is in honor of Mrs. Albert B. Walker in recognition of her interest in the advancement of vertebrate paleontology.

Holotype.—Panhandle Plains Historical Society Museum no. 2155, skull and lower jaws of an adult individual found in the Clarendon beds.

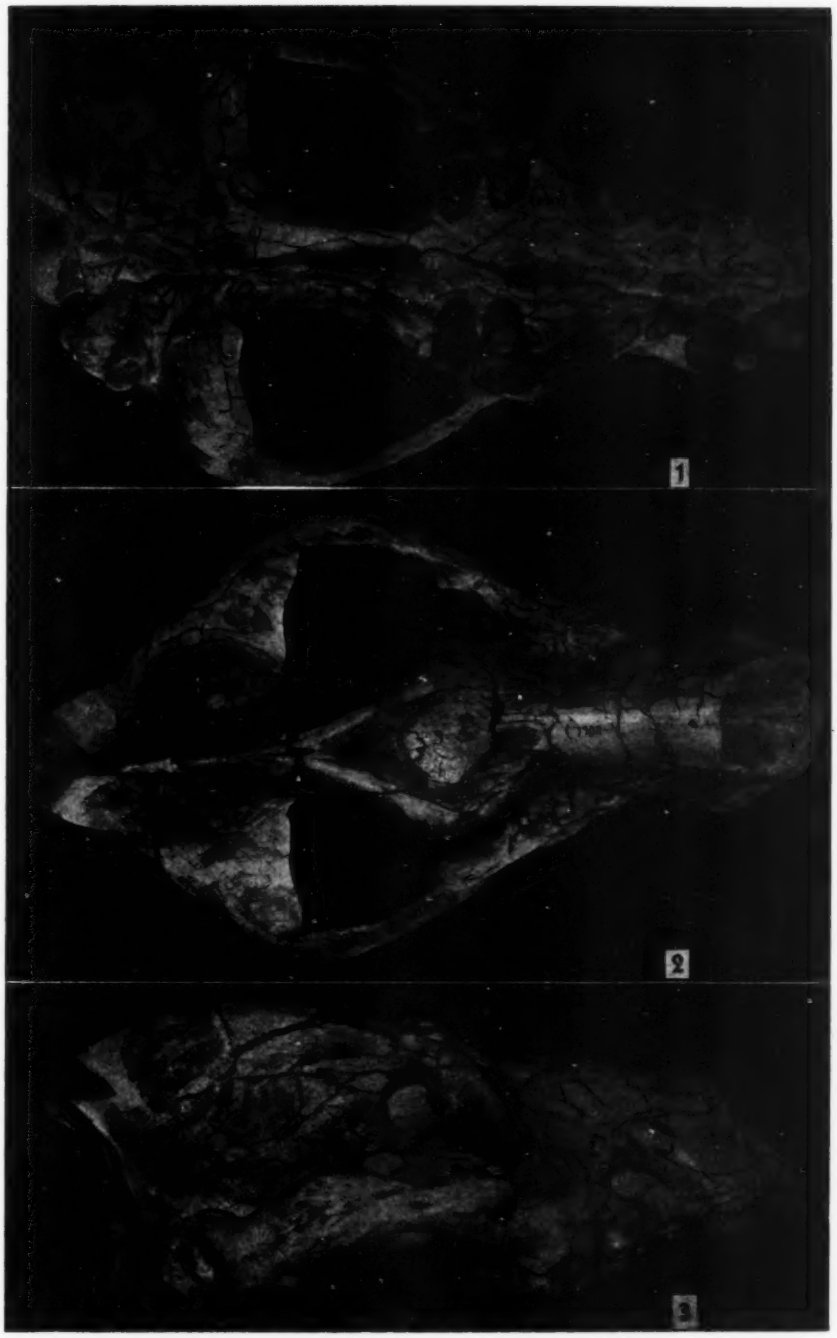
Type locality.—Adam Rizley ranch 1 mile east and ¾ mile south of Goldston, Texas, Donley County. SE ¼ SW ¼ sec. 21 block C-3.

Age.—Lower Pliocene, Clarendon fauna.

Diagnosis.—*Pliocyon walkerae* is considerably smaller than *Dinocyon gidleyi* Matthew (1902) from the Clarendon beds of Donley County, Texas, and later referred by Matthew (1924) to the genus *Pliocyon*. The skull of *Pliocyon medius* Matthew (1918) is smaller than that of the species described in this paper by approximately 60 mm.

M^3 and P_1 are absent in this species. M^1 and M^2 are similar in proportion and construction, but they are definitely subequal. Although P^4 is less massive than M^1, its anteroposterior diameter is greater by 9 mm. No anterior-internal cusp is present on P^4. The premolars are small and short. The central cusp is well-developed on P_2 and P_3. P^2 is smaller than P^3. Both P^2 and P^3 are double-rooted and set obliquely at an angle of approximately 45°. In *P. medius*, P^2 and P^3 are double-rooted, but they differ from similar teeth in *P. walkerae*, in which P^2 is not set at an angle while P^3 is placed at an angle of approximately 65°.

The canines are large, wide anteroposteriorly, very prominent, and directed sharply downward. The carnassial teeth and the first and second molars are the strongest teeth in the lower dental series. M_3 is small, almost vestigial, in proportion to the other molars, single-rooted, and situated in the base of the ascending ramus. The coronoid processes were apparently not high, but fragments are missing, and accurate measurements could not be made. The nasal bones project farther anteriorly than those of *P. gidleyi* and *P. medius*.



FIGS. 1–3.—*Pliocyon walkerae* Johnston and Christian, n. sp. Ventral, dorsal, and lateral views of skull, approximately ×½.

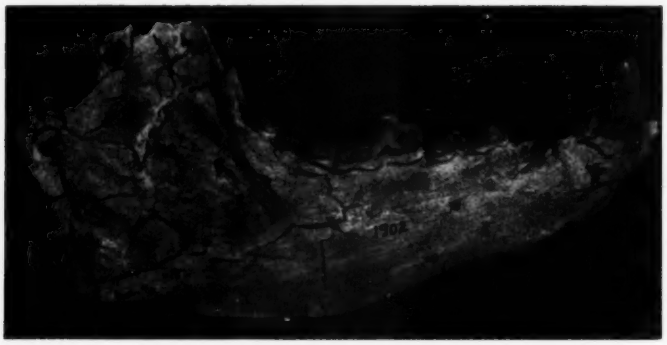


FIG. 4.—*Pliocyon walkerae* Johnston and Christian, n. sp. Lateral view of lower jaws, approximately $\times\frac{1}{3}$.

The zygomatic arches are well-developed and extend forward to a point opposite the anterior margin of M^1. The tympanic bullae are comparatively small. The sagittal and lambdoidal crests are prominently developed.

The dental formula of *P. walkerae*, as in *P. medius*, is $\frac{3\text{-}1\text{-}4\text{-}2}{3?\text{-}1\text{-}3\text{-}3}$. But in *P. walkerae* the

FIG. 5.—*Pliocyon walkerae* Johnston and Christian, n. sp. Occlusal view of lower jaws, approximately $\times\frac{1}{3}$.

cheek series is 24.5 mm. longer. The length of the cheek series of *P. medius*, from the anterior margin of P^1 to the posterior margin of M^2, is 92.5 mm. *P. walkerae*, from the anterior margin of P^1 to the posterior margin of M^2, is 117 mm. long. M^1 and M^2 in *P. walkerae* are more trigonal than in *P. medius* and also more nearly equal. There is a well-developed anterior root on P^4. No anterior-internal cusp such as is present in *P. medius* Matthew (1918) is found in *P. walkerae*. The upper premolars are so crowded that the first premolars are located in such a way that their anterior margins extend forward approximately 6 mm. beyond the posterior margin of the canines, a condition not found in *P. gidleyi* or *P. medius*. The incisors in *P. medius* are not crowded, but in *P. walkerae* they are closely set, as shown by the alveolae. The upper premolars are much more closely set than in *P. gidleyi*. The skull is nearly one-fourth (98 mm.) shorter than *P. gidleyi*. M_3 is placed in the base of the ascending ramus at an angle, but in *P. gidleyi* it is not. M_3 and P_1 are absent as in *P. gidleyi* and *P. medius*.

In *P. gidleyi*, the maximum transverse diameter of P^3 is in the anterior third, but in *P. walkerae* the maximum transverse diameter of P^3 is in the posterior third. The mastoid processes are strongly developed, and the exoccipitals are curved posteriorly. The paracone and the metacone of M^1 in *P. gidleyi* are unequal, but in *P. walkerae* they are equal. In *P. walkerae* the protocone appears to be more rounded and less elongate.

According to Hatcher's (1894) description of *Aelurodon meandrinus* (later placed in the genus *Pliocyon* by Matthew, 1924), the placement of teeth in the lower jaws is similar to that of *P. walkerae* in that the anterior end of P_3 lies outside of the posterior root of P_2, a characteristic also found in *Hadrocyon mohavensis*. Unfortuntaely the description of the jaw of *Aelurodon* (*Pliocyon*) *meandrinus* is so incomplete that a thorough comparison with *P. walkerae* is not possible. However, the smaller size of *P. walkerae* appears to validate it as a distinct species.

MEASUREMENTS OF THE SKULL

	Mm.
Length of skull	353
Greatest breadth across zygomatic arches	207
Breadth across postorbital processes	85.6
Distance from intersection of temporal impression to posterior dorsal extremity of skull	124
Distance from line through postorbital processes to posterior dorsal extremity of skull	185
Vertical diameter of orbit	49.2
Transverse diameter of orbits (estimated)	35.6
Width across occipital condyles	65.8
Transverse diameter of foramen magnum	26.2
Vertical diameter of foramen magnum	24.4
Length of palate from median incisive border to anterior edge of postpalatal notch	156
Width of palate between canines	45.6
Width of palate between anterior inner margin of P^4	47.5
Width of palate between posterior inner margins of P^4	83.1
Width of palate between inner margins of M^2	32.7
Width of postpalatal notch	14.5
Length of postpalatal notch	39.5
Vertical diameter of external auditory meatus	16
Anteroposterior diameter of tympanic bullae	26.5
Length of paroccipital processes	32.8
Breadth of skull at anterior ventral margins of orbits	112
Height of skull at intersection of temporal impressions	142
Length of nasals	85.2
Height of lambdoidal crest above foramen magnum	70.5
Breadth of skull at external alveolar borders of canines	88.4
Maximum height of zygomatic arch	55.8
Maximum width of braincase	81
Transverse diameter of external nares	40.3
Vertical diameter of external nares	39.2
Length of dental series, P^1-M^2	115

MEASUREMENTS OF THE LOWER JAWS

	Mm.
Length of mandible from condyles to anterior incisive border	268
Depth of jaw below M_1	57
Depth of jaw below P_2	46.5
Transverse diameter of condyle	52
Maximum thickness of jaw below M_1	25.2
Maximum width of symphysis opposite P_2	68
Length of dental series, P_2-M_3	131

DENTAL MEASUREMENTS (MM.)

	P^1	P^2	P^3	P^4	M^1	M^2	I^3	C
Anteroposterior diameter:	11.0	14.7	17.6	33.8	24.8	19.7	21.9	25.0
Transverse diameter:	7.4	8.9	10.5	19.4	28.8	30.8	15.8	18.8
	P_2	P_3	P_4	M_1	M^2	M_3	I_2	C
Anteroposterior diameter:	11.4	17.8	21.0	38.8	24.5	11.8		22.4
Transverse diameter:	9.0	10.0	10.5	16.4	17.0	11.0		17.8

RELATIONSHIPS

According to Matthew (1924) the genera *Amphicyon* and *Pliocyon* have a common ancestor in *Daphaenodon* of the lower Miocene and have developed by divergent specialization. Comparison with *Daphaenodon* shows a reduction of premolars in *P. walkerae*, as in other species of the genus Pliocyon; M^2 tends to become enlarged; M^3 lost; the incisors and canines are much larger; the sagittal and occipital crests are higher; the zygomatic arches are wider and correspondingly heavier, and the mastoid processes are much larger. These characteristics show further progress along the line of *Daphaenus-Daphaenodon* (Matthew 1924).

Pliocyon walkerae, like other species of *Pliocyon*, is most closely related to *Amphicyon* in size and dentition, but differs from *Amphicyon* in that there is no heel on M_1 nor is there a crested hypoconid or inner entoconid on M_1; and P_1 and M^3 present in *Amphicyon*, are lost in *Pliocyon*. When the genera *Amphicyon* and *Pliocyon* became divergent *Amphicyon* tended to grow progressively larger. The larger species of *Amphicyon* are much larger than the species of *Pliocyon*, and the teeth are heavier. There tends to be a shortening of the transverse diameter of the upper molars in *Amphicyon*, but in *Pliocyon* a widening is observed. The lower molars in *Amphicyon* are more bunodont than those of *Pliocyon*, thus showing a specialization of the *Amphicyon* teeth over *Pliocyon*.

P. walkerae bears a vestigial accessory cusp behind the principal cusp of P_4 thus differing from *H. mohavensis*, in which the accessory cusp is well developed. P_2 in *P. walkerae* is situated farther toward the inner side of the jaw than P_3, but in *H. mohavensis* the dental series is more nearly straight.

CONCLUSIONS

Characteristics of this large canid that afford it specific rank are: absence of the anterior internal cusp on P^4 as compared with other members of this genus; extension of zygomatic arches anteriorly to a point opposite M^2, and crowding of upper premolars and placement in maxillary at an oblique angle.

The skull indicates an animal smaller than *P. gidleyi*, larger than *P. medius*. Other intermediate characteristics are: the canines are larger than those of *P. medius*, smaller than *P. gidleyi;* there is more crowding of the upper dentition than in *P. medius*, less than in *P. gidleyi*.

REFERENCES

FRICK, CHILDS, *1926*, The Hemicyoninae and an American Tertiary bear: *Am. Mus. Nat. History, Bull.*, vol. 56, art. 1.

LONGWELL, KNOPF, FLINT, *1939*, *Physical Geology*, (Pt. 1): 2nd. ed., John Wiley and Sons, Inc., New York.

MATTHEW, W. D., *1902*, A skull of *Dinocyon gidleyi* from the Miocene of Texas: *Am. Mus. Nat. History, Bull*, vol. 16, art. 11.

——, *1918*, Contributions to the Snake Creek fauna: *idem*, vol. 38, art. 7.

——, *1924*, Third contribution to the Snake Creek fauna: *idem*, vol. 50, art. 2.

STOCK, CHESTER and FURLONG, E. L., *1925–27*, A new canid and rhinoceratid remains from the Ricardo Pliocene of the Mohave Desert, California: *California Univ., Dept. Geol. Sci., Pub.*, vol. 16, no. 2.

JOURNAL OF PALEONTOLOGY, VOL. 15, NO. 1, PP. 61–67, PLS. 9–11, 1 TEXT FIG., JANUARY, 1941

CRETACEOUS OPHIURANS FROM TEXAS

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ABSTRACT—The species *Ophiura texana* (Clark) and O. *graysonensis* (Alexander) are redescribed and more fully illustrated. Both are from the Lower Cretaceous deposits of Texas. The new species *Ophiura travisana* from the Upper Cretaceous of Texas is described. These three are the only known Cretaceous ophiurans from Texas.

THE AUTHOR wishes to express his appreciation to Dr. L. W. Stephenson for permission to describe a new Cretaceous form from Texas. He is indebted to Dr. Gayle Scott of Texas Christian University for the loan of the types of *Ophioglyphea graysonensis* Alexander and for additional specimens which have been designated as topotypes. Likewise he is indebted to the United States National Museum for the loan of the type of *Ophioglyphea texana* Clark. For the illustrations the author wishes to thank the United States Geological Survey.

This paper was written because of the need for more detailed descriptions and adequate illustrations of the two already described Cretaceous ophiurans from Texas. Also included in it is the new description of a third ophiuran from the Cretaceous of Texas. Very little is known concerning Cretaceous ophiurans; only 18 different species have been described, and a large proportion of these were found and described by Europeans. North America is very poorly represented, for these three from Texas are the greatest number from any one region.

Class OPHIUROIDEA
Order CHILOPHIURIDA
Family OPHIOLEPIDIDAE
Genus OPHIURA Lamarck
OPHIURA TEXANA (Clark)
Plate 9, figure 11; plate 10, figures 9, 11

Ophioglypha texana CLARK, *1893*, U. S. Geol. Survey, Bull. 97, p. 30, pl. 4, figs. 1*a–c*.
Ophioglypha texana CLARK, *1915*, *idem*, Mon. 54, p. 43, pl. 8, figs. 3*a–c*.

This species is based upon three poorly preserved forms on a single slab of limestone. The ventral side of each is exposed. Because of weathering, very few of the specific characters are preserved.

Ventral side of disk (*pl. 10, fig. 11*).—Because of wear, very little can be seen of this side of the disk. The section between the arms covered by small rounded overlapping plates is visible on one specimen. It shows part of the oral shield, with adoral margin forming acute angle, but the aboral margin is destroyed. Side mouth shields flank adoral margin of oral shield. The remainder of the disk is composed of a jumble of mouth parts and the adoral ends of the arms.

The diameter of the disk as given by W. B. Clark (4 mm.) is incorrect because part of the disk was destroyed in cleaning the specimen to the aboral end of the oral shield. Careful examination of the type shows the margin of the disk, which is 11 mm. across. Arrows indicate margin of disk. The other two specimens show diameters ranging from 10 mm. to 12 mm.

Ventral side of arms (*pl. 10, fig. 9*).—Most of the ventral arm plates are lacking, but where present they appear narrower and longer towards the aboral parts of the arms. The plates form in general a truncated triangle whose base is aboral in position. The lateral sides are bisinuate, sinuses equal in size. The first ventral arm plate is shorter and broader than the rest, having a single sinus on the lateral sides, the adoral margin curved. The ventral ends of the lateral arm plates appear as thick massive plates, with circular sinus in ventral margin for tentacle pore. The arm segments preserved on the type (including first ventral arm plate) number 51, 45, 6, 22, and 44.

Dorsal arm plates (*pl. 9, fig. 11*).—The ventral surface of several dorsal arm plates are exposed where the rest of the arms are destroyed. The position of these plates on the arm is similar to that of the ventral arm plates. The outline of the individual plates is in general a truncated triangle. The broad base is aboral in position.

Vertebral ossicle.—Only the ventral side of these ossicles, showing only the broad deep lower canal furrow, is exposed. The ossicles articulate on each other by zygosphenes, zygocondyles and sockets and not as a system of hour-glass articulation.

Location.—Six miles north of Fort Worth, Texas, on the banks of Fossil Creek.

Geologic horizon.—Weno clay member of Denison formation of the Washita group, Comanche series (Lower Cretaceous).

Type.—U. S. Nat. Mus. no. 21884.

OPHIURA GRAYSONENSIS (Alexander)
Plate 9, figures 1, 10; plate 10, figures 1, 6, 7, 10; pl. 11, figs. 8, 10

Ophioglypha graysonensis ALEXANDER, *1931*, Jour. Paleontology, vol. 5, no. 2, pp. 152–153, pl. 20, figs. 19, 20.

The writer feels justified in redescribing and figuring this species of ophiuran because many of the essential details, necessary for understanding both the fossil and recent forms, are not discussed in the original description.

Alexander assigned this new species to an invalid genus. Bell[1] showed that the generic name *Ophiura* should replace *Ophioglypha*, but this change was not generally adopted until around 1900, since which time the true Ophioglyphas have been placed in *Ophiura*. Doubtless Alexander followed Clark's treatment of *Ophioglypha texana* (1893, 1915).

Ophiura graysonensis must have been a very shallow water form, because tests of *Globigerina* and *Textularia* are cemented to the disk. In addition there are great numbers of echinoid spines on the surface of the matrix in the type specimen. These spines are all oriented in one direction, which could only have been caused by current action in very shallow water.

[1] BELL, F. J., *1891*, *Ann. and Mag. Nat. History*, ser. 6, vol. 8, p. 339.

Dorsal side of disk (*pl. 9, fig. 1*).—In the center of the disk is the central disk plate, which is circular in outline. This plate overlies five small plates, which in turn overlie five more plates and so on. Each of these plates is somewhat broader then the preceding but is exposed for about the same length. From this central rosette of similar-sized plates there radiate ten rays, five of which are embraced by the pairs of radial shields and five between the respctive pairs. The rays between the right and left radial shields are composed of three plates. The most adoral one has a rounded aboral margin and is about equidimensional in all directions. Aboral of this plate is a long, narrow, wedge-shaped plate, which lies between the radial shields. Aboral of this is a very small oval plate, which in the type specimens is missing in two places. This small oval plate is just adoral of the first dorsal arm plate and between the comb plates. The rays between adjacent pairs of radial shields are composed of several large oval plates, their longest axes radial in position, which overlap much smaller plates on their margin. Radial shields as exposed are triangular-ovate in outline, with an apparently straight inner margin and a rounded outer one. The radial shields are overlapped by surrounding plates which obscure the true outline.

There are no true interradial marginal plates, the area being occupied by a number of small plates. The comb plates are poorly shown on the type. No comb papillae can be observed. The first, second, and third—the last questionably—dorsal arm plates are incorporated in the disk. The diameter of the disk showing the dorsal surface is 10.5 mm.

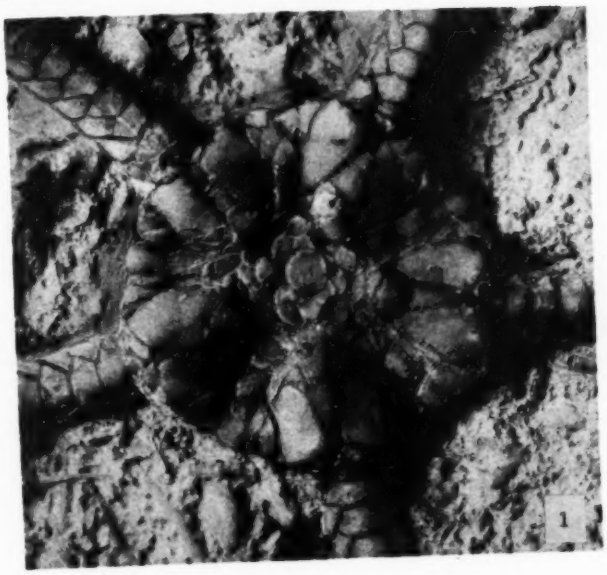
Variations.—In some of the other specimens the number of plates which compose the central rosette are greater than in the type specimen. Likewise the long plates between the radial shields in some specimens

EXPLANATION OF PLATE 9

FIGS. *1, 10—Ophiura graysonensis* (Alexander). Dorsal and ventral views of syntypes, Texas Christian Univ. 1067, ×5. (p. 62)

2–9, 12–14—Ophiura travisana C. Berry, n. sp. *2, 3*, Ventral and dorsal surfaces of oral shield, ×13. *4, 5*, Ventral and dorsal surfaces of comb plate, ×13. *6, 7*, Inside and outside surfaces of lateral arm plate, ×13. *8, 9*, Dorsal and ventral surfaces of dorsal arm plate, ×13. *12, 14*, Dorsal and ventral surfaces of jaw, ×13. *13*, Spine, ×13. (p. 64)

11—Ophiura texana (Clark). Ventral surface of dorsal arm plate of holotype, U. S. Nat. Mus. 21884, ×13. (p. 61)



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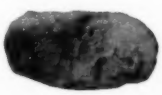

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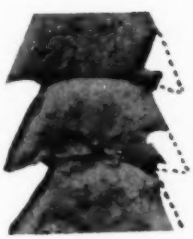

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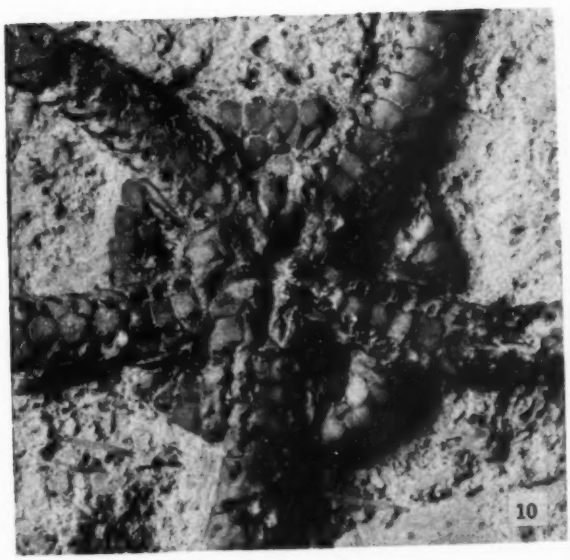

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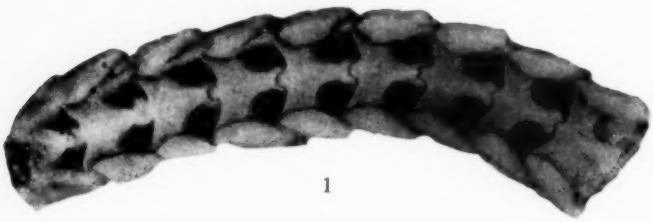
C. Berry, Cretaceous Ophiurans



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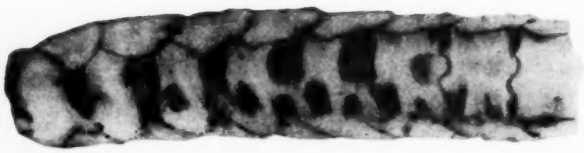

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C. Berry, Cretaceous Ophiurans

are paired instead of being a single plate, as in the type. In better-preserved parts of the disk the comb plate is not a single plate but is composed of three sections, the dorsal one being the largest. None of these show evidence of comb papillae.

In none of the specimens at the writer's disposal is the surface of the disk flat and even but so compressed that the region of the radial shields underlain by the jaws are much more elevated than in the intervening region. This warping of the disk surface has undoubtedly distorted somewhat the true relationship of the smaller plates.

Dorsal side of arms (*pl. 11, fig. 8*).—The arms, sigmoid in attitude, show a high degree of flexibility on the horizontal plain. The dorsal surface of the arm is covered by a series of highly arched dorsal arm plates, which become narrower towards the aboral end of the arm. The outline of the individual plates is in general a truncated triangle with its broad base aboral in position. The sharp dorsal ends of the lateral arm plates flank the dorsal arm plates.

None of the dorsal ends of the arms are preserved. The parts of the arms that are preserved are composed of 24, 34, 22, 38, and 14 segments.

Ventral side of disk (*pl. 9, fig. 10*).—Center of disk occupied by a wide-open mouth showing end of jaws, side mouth shield, and oral shield. Whether or not teeth were present in the type is unknown. Side mouth shield flanks adoral angle of oral shield. Lateral sides of oral shields slightly concave. Aboral end of plate rounded. Part of disk aboral of oral shield covered by a number of irregularly rounded disk plates. These parts of the disk are depressed unevenly, so that the arrangement of plates is altered slightly. The adoral portions of the arms stand above the rest of disk. Five of the ventral arm plates are incorporated in disk. Tentacle pores between ventral arm plates and lateral arm plates, number of scales cannot be observed on type. Genital slits cannot be observed on type. The diameter of the disk is 10 mm.

Variations: The oral shield in the majority of disks shows a greater concavity on their lateral sides and the plates are somewhat broader.

Ventral side of arm (*pl. 11, fig. 10*).—The arms, which are sigmoid in attitude, are covered on ventral side by ventral arm plates, which decrease in breadth and increase in length towards aboral end of arm. The shape of these plates is in general a truncated triangle whose curved base is aboral in position. The lateral sides are bisinuate. The larger sinus is aboral in position and forms part of margin of tentacle pore. Adoral sinus contacts lateral arm plate. The first ventral arm plate is much shorter and not so broad as the others, and has only one sinus on lateral sides and a rounded adoral end. Flanking the ventral arm plates are the ventral ends of the lateral arm plates. These two plates form the side of the tentacle pores, which are larger and more pronounced near the disk than elsewhere on arm. In this specimen the arms are much longer than in the one showing the dorsal view, having 19, 46, 41, 49, and 46 ventral arm plates.

ADDITIONAL CHARACTERS

Certain important characters that do not appear on the syntypes can be discerned on several fragments which were collected from the same locality and horizon and definitely belong to the same species.

Teeth.—Teeth triangular, with curved sides and swollen surface. Two specimens of broken disks expose in cross section the teeth of the jaws. In both specimens five teeth were counted.

Arm spines (*pl. 10, fig. 6*).—Spines short and stylate, four to each lateral arm plate, appressed. Ventral two same length. The remaining two decrease in size. Neither of the two syntypes shows the spines but on many of the individual broken sections of the arms the spines were preserved. Just

EXPLANATION OF PLATE 10

FIGS. *1, 6, 7, 10—Ophiura graysonensis* (Alexander). *1, 7,* Dorsal and lateral views of ground sections of arms, ×13. *6,* Arm spines, ×13. *10,* Ventral surface of tentacle scales, ×15. (p. 62)

2–5, 8—Ophiura travisana C. Berry, n. sp. *2, 8,* Inside and outside surfaces of jaw, ×13. *3, 4,* Ventral and dorsal surfaces of ventral arm plate, ×13. *5,* Tooth, ×13. (p. 64)

9, 11—Ophiura texana. Ventral surface of disk, ×5. (p. 61)

where in the arm these sections belong cannot be ascertained, but they all carried four spines.

Tentacle scales (pl. 10, fig. 10).—The first seven tentacle pores are covered by two thin semicircular scales. No tentacle scales are preserved on the syntypes. Whether the rest of the pores were covered by scales cannot be discerned.

Genital plate.—Ventral side of genital plate is a long, arched, stylate plate. Lateral side similar in shape but aboral end swells into a large irregular condyle whose features cannot be distinguished. Two broken disks give these very incomplete views of the genital plate.

Vertebral ossicle.—The actual surface of the ossicle can be partly seen in two exceptional fragments. In all other individuals the entire animal has calcified, not only the plates but also the intervening spaces.

Aboral side: Articulating area composed of centrally located rectangular zygosphene, flanked on dorsal portion by two similarly shaped but smaller zygocondyles. From this articulating area the surface slopes suddenly away to broad parapophyses in dorsal region. The anterior hypapophyses separated by broad deep lower canal furrow.

Ventral side: Lower canal furrow crosses center of plate. It is flanked on each side by a broad high ridge. This is all that can be discerned of the ventral side.

In order to get some conception of the vertebral ossicles two fragments of the arms were ground down at a sharp angle, one a dorsal cut (pl. 10, fig. 1) and the other a lateral cut (pl. 10, fig. 7). This cutting shows a series of cross sections. That part within the arm occupied by the muscle shows the calcite darkened by the muscle fibers.

Location.—East bank of Village Creek, 100 yds. south of bridge, 2 mi. east of Everman on Everman-Kennedale road, southeast of Forth Worth, Texas.

Geologic horizon.—Grayson marl member of Denison formation of Washita group, Comanche series (Lower Cretaceous).

Types.—Texas Christian University 1067; topotypes, Johns Hopkins University.

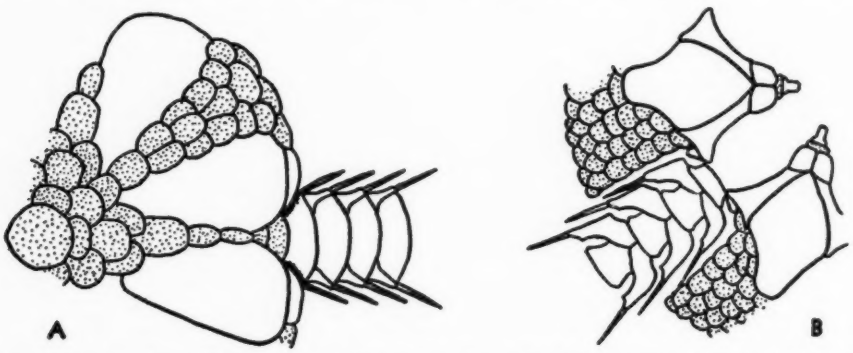

FIG. 1.—*Ophiura travisana* C. Berry, n. sp. Reconstruction; stippled plates are hypothetical. *A*, Dorsal surface of disk; *B*, ventral surface of disk.

OPHIURA TRAVISANA C. Berry, n. sp.
Plate 9, figures 2–9, 12–14; plate 10, figures 2–5, 8; plate 11, figures 1, 3, 4, 7, 11–15; text figure 1

This species is based upon some 272 disarticulated plates washed out of three pieces of clay each about 1 cc. in size. There are no discrepancies among these plates, thus proving that they all belong to the same species if not to the same individual. The hypothetical reconstruction (text fig. 1) gives some idea of the arrangement of the more important plates of *Ophiura travisana*. The assignment to this genus is based upon the presence of the comb plate. The specific name was taken from Travis County, Texas, where the specimen was collected by Dr. Julia Gardner.

Radial shield.—Dorsal surface: Outline a modified right-angled triangle with rounded corners. Inside-aboral corner truncated. Surface arched slightly, pitted, lateral edges

beveled, showing that it was overlapped by abutting plates.

Ventral surface (pl. 11, fig. 3): Outline same as in reverse view. Surface smooth, concave. Center of aboral margin is raised area for articulation with the genital plate.

The type plate, which is the left one, is 1.29 mm. long, 0.88 mm. wide.

Comb plate.—Outside surface (pl. 9, fig. 5): Outline a modified spherical triangle, one side slightly concave, the longest side bisinuate, one sinus longer than the other. Surface in general arched, somewhat uneven. Whether this plate possessed comb paillae cannot be ascertained.

Inside surface (pl. 9, fig. 4): Outline same as in reverse view. Surface very uneven; rises very suddenly from a narrow groove along longest sinus of longest side, to an undulating concave surface. The surface rises steeply from the side, which is concave.

Type plate, 0.76 mm. long, 0.47 mm. wide.

The presence of this comb plate, of which unfortunately only one was found, places this Lower Cretaceous ophiuran in the genus *Ophiura*.

Dorsal arm plate.—Dorsal surface (pl. 9, fig. 8): Outline in general that of a spherical equilateral trapezoid with rounded corners, lateral edges converging towards adoral side. Surface of plate smooth but highly arched.

Ventral surface (pl. 9, fig. 9): Outline same as in reverse view. Surface concave.

Type plate, 0.82 mm. long, 1.47 mm. wide.

The dorsal arm plates vary in size and proportions, depending on location in the arm. The more aboral ones become flat and equilateral.

Side mouth shield.—Outside or ventral surface (pl. 11, fig. 13): Triangular in outline, twice as high as wide, base tapering to a centrally located sharp narrow lobe, which curves dorsally. Surface of plate uneven, inner third of surface on slightly lower plane than rest of plate, which is overlapped by oral shield.

Inside or dorsal surface (pl. 9, fig. 12): Outline same as in reverse view. Surface very uneven, rising at aboral end into a narrow highly elevated lobe.

The type plate, a right one, 0.82 mm. long and 0.53 mm. wide.

Oral shield.—Ventral surface (pl. 9, fig. 2): Outline cordate, with broad, flat, rounded process at larger or aboral end. Adoral end sharply pointed. Surface of the plate highly arched transverse to shortest axis.

Dorsal surface (pl. 9, fig. 3): Outline same as in reverse view. Surface of plate very uneven. In adoral part surface slopes up from lateral sides to ridge in center of plate. In aboral part the sides rise vertically to a high flat elevated region, in the center of which is a slight depression.

Type plate, 1.12 mm. long, 0.82 mm. wide.

This oral shield is very distinctive in outline. In a less mature oral shield the plate has a much shorter adoral-aboral axis.

Jaw.—Dorsal surface (pl. 9, fig. 12): Outline a modified rectangle, tapering slightly towards adoral end. Surface very uneven, high narrow adoral end separated from the rest of the plate by a U-shaped groove for the circumoesophageal nerve ring. Aboral end rises slightly to form ala for aboral articulating area. Depression along outside edge of jaw for oral tentacle. Surface in general rounds down towards lateral sides.

Inside surface (pl. 10, fig. 2): Outline rectangular, being somewhat constricted near adoral end. Surface of plate uneven, lateral sides round down. Aboral end occupied by articulating surface for vertebral ossicles. Adoral part slants down to adoral end. Center of surface is high, being covered with matrix in this specimen.

Ventral surface (pl. 9, fig. 14): Outline same as in reverse view. Surface curves down to lateral sides, otherwise smooth, except near aboral end, where there is a slight depression, which crosses the plate obliquely.

Outside surface (pl. 10, fig. 8): Outline same as in reverse view. Surface very uneven, along ventral edge of plate is an irregular raised ridge, dorsal of which in center of plate is a deep semicircular depression for location of oral tentacle. Aboral part of surface irregularly sculptured for contact with other half of jaw.

The type plate, the left half, 0.82 mm. long, 0.59 mm. high, 0.29 mm. in maximum thickness.

Tooth.—Only one tooth (pl. 10, fig. 5) was

found. This was broad and flat, the adoral end rounded, the aboral end swollen. This tooth must have come from an older individual than most of the plates, because its size is out of proportion to the rest of the plates found.

Lateral arm plate.—Outside surface (pl. 9, fig. 7): Rectangular in outline, adoral margin slightly concave. In aboral-ventral corner is a deep semicircular sinus. Surface of plate highly arched parallel to long axis of plate. Surface pitted, except for narrow band along adoral margin. Two small raised areas on aboral margin for articulation of spines.

Inside surface (pl. 9, fig. 6): Outline same as in reverse view. Surface in general concave, higher in center part than at aboral or adoral ends, a deep U-shaped groove runs at right angles to ventral margin of plate from sinus on aboral-ventral corner.

Type plate, the right one, 0.88 mm. long and 0.35 mm. high.

These lateral arm plates increase in length towards the aboral end of the arm. Those near the adoral end (pl. 11, fig. 1) of arm, especially the ones incorporated in the disk, are very short and high, thus the dorsal and ventral margins have become rounded.

Ventral arm plate.—Ventral surface (pl. 10, fig. 3): Outline a modified triangle, lateral sides bisinuate, aboral sinus broader and deeper than adoral one. Surface smoothly arched.

Dorsal surface (pl. 10, fig. 4): Outline same as in reverse view. Surface uneven, a broad shallow groove running down center of plate. Aboral part beveled, forming a thin aboral edge.

Type plate, 0.59 mm. long, 0.65 mm. wide.

The outline of these ventral arm plates varies depending on their location in the arm. The more aboral the location, the longer the plates and the more pronounced the sinuses. The adoral plates show a very shallow (if any) aboral sinus on lateral side. Plate appears as if belonging to a different species so great is the change.

Genital plate.—A long stylate plate tapering from a large irregular-shaped end to a thin, sharp point has been recognized as the genital plate. In the narrow part there is a shallow groove down the side as in the adoral portion of the usual genital plate. Unfortunately this plate is broken in half and can not be illustrated.

Vertebral ossicle.—Adoral surface (pl. 11, fig. 4): Outline a modified oval, indented in center of ventral side by a U-shaped lower canal furrow. Surface of plate uneven, divided into four quadrants by raised areas. Lower alar area more indented than upper. Due to condition of plate articulating area cannot be discerned.

Aboral surface (pl. 11, fig. 7): Outline same as in reverse view. Surface of plate very uneven; a high central articulating area whose actual means of articulating is obscured by condition of plate. This area is flanked in dorsolateral corners by the parapophyses, which recede very rapidly. The configuration dorsal to the raised area is undiscernible.

Lateral surface (pl. 11, fig. 11): Outline rectangular, on the aboral margin the zygocondyles extend beyond the rest of the side. These zygocondyles could not be seen in aboral view because they are worn and covered by matrix, which it is unsafe to remove. The outline of the zygosphene cannot be seen. The surface of the plate is very uneven, rising from aboral towards adoral side to form winglike parapophysis. The anterior and posterior hypapophyses are visible in ventral portion of plate.

Dorsal surface (pl. 11, fig. 14): Outline irregular, somewhat triangular, with broadest

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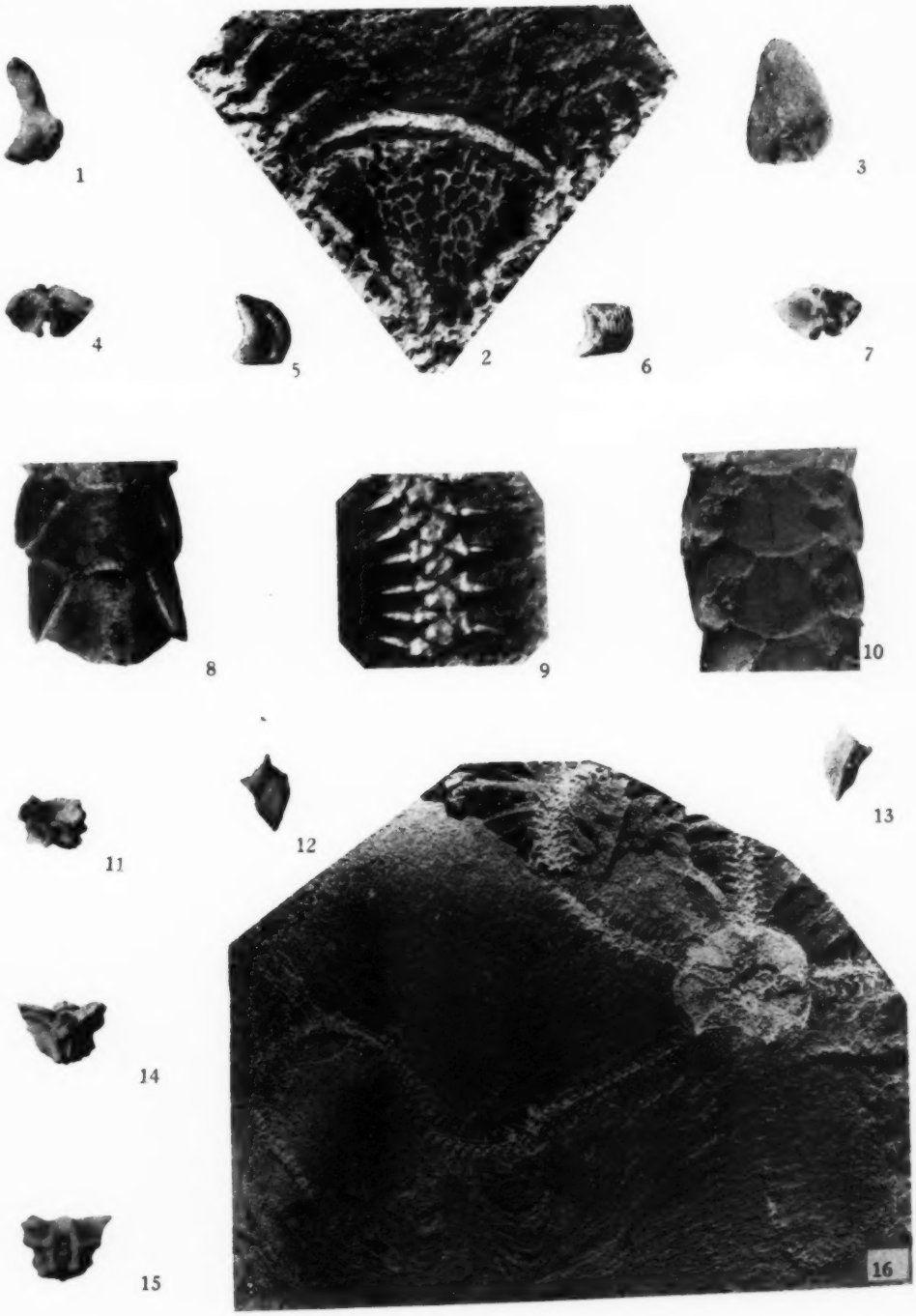
EXPLANATION OF PLATE 11

FIGS. *1, 3, 4, 7, 11–15—Ophiura travisana* C. Berry, n. sp. *1*, Lateral arm plate near disk, ×13. *3*, Ventral surface of radial shield, ×13. *4, 7*, Adoral and aboral surfaces of vertebral ossicle, ×13. *11, 14, 15*, Lateral, dorsal, and ventral surfaces of vertebral ossicles, ×13. (p. 64)

2, 9, 16—Amphioplus venezuelanus C. Berry, n. sp. *2*, Section of disk showing plates, ×12. *9*, Ventral arm plates, ×12. *16*, Dorsal surface, ×3. (p. 68)

5, 6—Ophiura sp. Lateral arm plates, ×15. (p. 70)

8, 10—Ophiura graysonensis (Alexander). *8*, Dorsal surface of dorsal arm plates, ×13. *10*, Ventral surface of ventral arm plates, ×13. (p. 62)



C. Berry, Cretaceous and Tertiary Ophiurans

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side adoral. Surface very uneven, upper alar ridge crosses adoral side of plate. The dorsal edges of the parapophyses run from aboral end of plate to adoral end flaring out to lateral corners. From this high ridge the surface slopes down to ventral side.

Ventral surface (pl. 11, fig. 15): Outline same as in reverse view. Surface very uneven, across center of plate in adoral-aboral direction is a deep U-shaped lower canal furrow. Separating this canal furrow from the rest of the plate is a high steep-sided ridge, lateral of which are the anterior and posterior hypapophyses as secondary ridges, being separated by a deep depression. The greater part of lower canal furrow filled by matrix. Type plate, 0.29 mm. from the base of each canal furrow on the adoral side, 0.65 mm. long, 0.88 mm. in greatest dimension across adoral face.

The location of this ossicle is somewhere near the disk. Several ossicles were found which undoubtedly came from the aboral section of the arm. These ossicles were very thin and two or three times as long as broad. The features on the adoral and aboral ends have not been developed to an extent where they can be discerned. These aboral vertebral ossicles were found in the long lateral arm plates, thus indicating their position.

Spine.—Spine (pl. 9, fig. 13) long and stylate, round in cross section, with a smooth surface. Type specimen 0.76 mm. long.

Location.—U. S. Geol. Survey station 13910, bank of Colorado River, Webberville, Travis Co., Texas.

Geologic horizon.—Kemp clay of Navarro group, Upper Cretaceous.

Types.—U. S. Nat. Mus. 76415.

JOURNAL OF PALEONTOLOGY, VOL. 15, NO. 1, PP. 68–70, PL. 11, JANUARY, 1941

TERTIARY OPHIURANS FROM VENEZUELA

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The Johns Hopkins University, Baltimore, Md.

ABSTRACT—Eocene lateral arm plates of the genus *Ophiura* are reported from well samples and surface samples from Venezuela. The new species *Amphioplus venezuelanus* from a Miocene well core which was taken at the depth of approximately 5300 ft. is also described.

THE AUTHOR wishes to express his thanks to Drs. H. D. Hedberg and G. E. Manger of the Mene Grande Oil Co. of Venezuela for the material upon which this article is based. This material consists of a well core of Miocene age and an outcrop sample, and core samples from several wells, all from the Eocene.

In a core from a well in the State of Anzoategui at a depth of 5300 ft. there is preserved a nearly complete ophiuran. As the ophiuran lies near one side of the two inch core, some of the arms are cut off. The material of the core is a very fine shale and is of Miocene age.

The core is split so that one part shows the inside view of the dorsal disk plates and the other shows their impression on the sediment which apparently filled the space between the dorsal and ventral sides of the disk. No true ventral surface of the disk can be observed. The thick plates, like the jaws, are split more or less in half and appear on both pieces. As the arms, which show a high degree of horizontal flexibility, do not lie exactly flat, various parts of the ventral and dorsal surfaces of the arms are exposed. The arm spines stand out at right angles to the arm.

Class OPHIUROIDEA
Order LAEMOPHIURIDA
Family AMPHIURIDAE
Genus AMPHIOPLUS Verrill
AMPHIOPLUS VENEZUELANUS C. Berry, n. sp.
Plate 11, figure 2, 9, 16

Disk.—Upon first examination the surface of the disk appeared as if it were covered by granules, but this was due to the reticulate structure of the plates impressed upon the very fine sediment. The dorsal side of the disk is composed of right-angled scalene triangular radial shields, but the area between these shields is covered by small oval plates, whose longest axis is radial in position. In all probability the center part was likewise covered. The genital plates lie parallel to the adoral ends of the arms, whose vertebral ossicles are cross sectioned horizontally, there being about five ossicles within the disk. Nothing concerning the jaws can be distinguished beyond the fact that there were five pairs. There is no evidence of comb plates. This is a very small form, the diameter of the disk being only 6.06 mm.

Arms.—The arms, which indicate a great deal of adaptation for horizontal movement, show absolutely no evidence of dorsal arm plates. Because of the excentric location of the ophiuran in respect to the core, the arms have varying lengths, there being 74 segments in the longest, 36, 9, and 8 segments in three others, and the remaining arm is partly buried and the number of segments can only be estimated at approximately 45–50. In the longest arm the aboral end is destroyed so that the true length cannot be ascertained.

The absolute lack of dorsal arm plates is perplexing because the ventral arm plates are so well developed (pl. 11, fig. 9). In no instance is there any indication that dorsal arm plates were present when the animal was covered. If the dorsal arm plates were present they probably were spherical equilateral trapezoid, as is the general shape for this family. The dorsal side of the arms is open, showing the dorsal ends of the lateral arm plates and the dorsal side of the vertebral ossicles.

Each lateral arm plate had three smooth-surfaced stylate spines. In cross section these spines are circular. These spines in every instance stand at right angles to the arm. This is the most striking feature of the arms.

The ventral side of the arms is covered by ventral arm plates of equal size. These plates are in outline a modified equilateral spherical triangle whose aboral corners are rounded, and in the center of each lateral side is a sharp-pointed lobe. Aboral part of plates has nearly parallel lateral edges. Adoral half slightly concave.

The lack of the dorsal arm plates and the breaking of the arm at various places show that the vertebral ossicles articulate by zygocondyles, zygosphenes and sockets instead of by an hour-glass type of articulation. The dorsal edge of the alar and the upper canal furrow is exposed in the majority of segments. Nowhere can the true articulating surface be seen.

The specific name *venezuelanus* is taken from the country in which the specimen was found.

In addition to the structural characters that place this Miocene specimen in the family Amphiuridae, there is the fact that these animals usually inhabit a muddy bottom lying just under the surface of the mud. The fossil specimen is preserved in a very fine mud, and the nearly perfect condition of the specimen indicates that it was covered with mud at the time of its death or otherwise the arms or disk in all probability would have been detached. As it is, the dorsal arm plates are entirely lacking.

The family Amphiuridae is divided by H. L. Clark[1] into 20 genera embracing some 352 species. Of these 20 genera 17 can be disregarded because they do not compare favorably with the fossil form. The three remaining genera, *Amphilepis*, *Amphiodia*, and *Amphioplus* are very closely related to each other and are separated in the living forms by characters which unfortunately are not preserved in the fossil. However, if one considers the arrangement of the small disk plates and the position of the radial shields, the genera *Amphilepis* and *Amphiodia* are eliminated, leaving the genus *Amphioplus* the closest to the fossil form.

According to H. L. Clark[2] the genus *Amphioplus* comprises 62 species; of this number only six could possibly be found in the Caribbean region. The remainder are found in the warmer waters of the Pacific. Most of these species inhabit shallow water, but some descend to such great depths as 2610 fathoms. The closest relative of this Miocene form represents a genus which is predominantly confined to the Pacific today, showing that during Miocene times there must have been some shallow water connection between the two oceans. This fact is substantiated by the closeness of other invertebrate faunas.

The geologic history of the family Amphiuridae is very limited, only three species being known fossil. The oldest form is *Amphiura pratii* from the Middle Oolitic formation of England. There is one Miocene form, *Amphiura sanctaecrucis* from California, and a Pleistocene specimen *Ophiocnida brachiata* from the Isle of Man. Hence this is the first time that the genus *Amphioplus* has been reported as fossil.

The reporting of this new form brings the total Miocene Ophiuroidea up to the small number of six species, a very few when we consider there are approximately 1400 living species in our seas today.

In a surface sample collected by Dr. G. E. Manger about 1 kilometer southwest of the town limits of Maracaibo in the State of Zulia there were 19 lateral arm plates and five vertebral ossicles. All of the lateral arm plates are similar but vary in size. The vertebral ossicles were badly worn. The age of this material is Upper Eocene, and the matrix is a calcareous glauconitic bed.

Order CHILOPHIURIDA
Family OPHIOLEPIDIDAE
Genus OPHIURA Lamarck
OPHIURA sp.
Plate 11, figures 5, 6

Lateral arm plate.—Outside view (pl. 11, fig. 6): Outline rectangular, adoral margin concave, aboral margin convex. Surface of plate highly arched.

Inside view: Outline same as in reverse view, surface concave, being higher near adoral end.

Plate is 0.53 mm. long and 0.47 mm. wide.

This plate is not the largest but is the best preserved. Most of the plates are covered with sand grains, which obscure the plate itself and are impossible to remove.

[1] CLARK, H. L., *1915*, Catalogue of Recent Ophiurans: *Harvard College, Mus. Comp. Zool., Mem.* vol. 25, no. 4, pp. 223–268.
[2] *Op. cit.*, pp. 251–258.

Vertebral ossicle.—These vertebral ossicles are in such poor condition that they do not warrant lengthy descriptions or illustrations. As all five plates came from different sections on the arm, no two are alike. On the aboral face they have a centrally located zygospene, which is flanked on the dorsal side by two zygocondyles. The dorsal side shows evidence of the upper canal furrow, while the ventral side shows a very broad lower canal furrow. The adoral face in no case is clean enough to identify parts.

The well samples come from four wells, and the ophiurans were found at various depths in each. Only the lateral arm plates were found. These lateral arm plates are the most numerous of all the plates in the animal, and consequently one would expect to find a large proportion of them. Whether or not other plates were overlooked or not preserved cannot be ascertained. The ophiurans from these various well samples probably represent the genus *Ophiura*. This scant supply of material does not warrant a more precise identification. In order to be more specific in the determination it is necessary to have an assemblage of the various plates to work with.

Lateral arm plates were found in a well near the north end of Lake Maracaibo in the State of Zulia. These plates were found in association with comatulid joints at depths of 1850–1925 ft. and from 3600–3625 ft. The presence of both kinds of animals definitely proves that these sediments were typically marine. The material in which these ophiuran remains were found is of Upper Eocene age.

In one of the wells located just offshore in the northern part of the District of Bolívar, State of Zulia, only two lateral arm plates were found, these coming from depths 3600–3650 ft. The material in which these plates were found is a greenish-gray fine- to medium-grained shaly calcareous sandstone. Neither of these two plates show sockets for articulation of spines, which indicates that in all probability the spines were appressed. The age of this material is uppermost Eocene (Jackson).

In a well very close to the preceding, 12 lateral arm plates were found. The material in which they were preserved is a greenish-gray fine- to medium-grained calcareous sandstone ranging from argillaceous to shaly. Like the material from the preceding well, these specimens are badly worn and their more distinctive characters are lost. These 12 plates were found at depths ranging from 3050 to 3300 ft. The age of the beds is uppermost Eocene (Jackson).

In a well on the west shore of Lake Maracaibo approximately 25 kilometers southwest of the town of Maracaibo, 25 Ophiuran plates were recovered. One of these plates, either a radial shield or a disk plate, was found at a depth of 2850–2900 ft. This plate was the only one found at this depth. The lack of lateral arm plates in association is unusual, especially since this is the first instance of plates other than lateral arm plates having been found. At various depths ranging from 4100 to 5050 ft. some 24 lateral arm plates have been found. One lateral arm plate (pl. 11, fig. 5) shows four sockets for spines. The placement of these sockets indicates appressed spines.

This is the first time that ophiurans of Tertiary age have been reported from the mainland of South America. Likewise it is the first time that their remains have been recognized in well cores. It is regrettable that their state of preservation is not better so that a more accurate determination could be made. The presence of ophiurans in a deposit indicates not only that one is dealing with a true marine deposit but also actual bottom conditions and not induced ones. In contrast foraminiferal tests and other microfossils are not definitely confined to marine waters, also because of their lightness they are often carried long distances from their normal environments before they become incorporated in other classes of sediments. Undoubtedly more and more ophiurans will be found in well samples when the paleontologists become aware of them. When this happens, the author feels that under certain conditions they will become useful for zoning.

The practically complete specimen in the well core from eastern Venezuela is interesting because of its condition of preservation at that depth and its age, as well as the fact that it happened to be struck by the drill. This last indicates in all probability that these Miocene beds contained a greater number of ophiurans than would be expected.

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MORPHOLOGY OF CONODONTS

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ABSTRACT—In this paper certain past views as to the nature of conodonts, in the sense of the peculiar bodies for which the term was proposed in 1856 by Pander, are briefly reviewed. A description is given of the minute structures observed in thin sections of certain Mississippian specimens, and an interpretation based on them is offered. The conclusions reached are these: (a) That conodonts are a valid morphologic unit, (b) that the so-called species of conodonts are quite variable entities, the individual changing greatly in ontogenetic development, and (c) that conodonts functioned as internal supports for tissues that were located at a place exposed to stresses upon the exterior of or within the bodies of some genetically related group of marine animals.

THIS PAPER is concerned with the morphology of the true conodonts, that is, with that group of laminated, toothlike, and platelike fossils that was named and described by C. H. Pander in 1856 in his *Monographie der fossilen Fische des silurischen Systems der russisch-baltischen Gouvernements.*

Although conodonts have been known for more than 80 years and are now regarded as useful in stratigraphy, their zoological relationships and the function they performed are still undetermined. That this condition would exist is easily explainable, for conodonts are but one of the many anatomical parts that must have been present in the living organism that bore them, and, as compared with other taxonomic groups, conodonts have few significant characters.

The present contribution is founded primarily upon a study of the structures observed in thin sections of some translucent specimens from two Mississippian formations—the Barnett shale of San Saba County, Tex., and a "Bushberg-Hannibal" horizon in Pontotoc County, Okla. The work of others, especially the above-mentioned work of Pander, has also been taken into account. The paper is intended to bring to attention certain features of conodonts that have not previously received much notice. The conclusions offered do not include an interpretation of the zoological relationships of these fossils, but it is hoped that the data recorded will be useful toward the ultimate solution of this question.

The writer wishes to express his appreciation of the assistance of Mr. W. Ayvazoglou, of the Geological Survey, in translating Pander's description and discussion.

DEFINITION OF TERM CONODONT

Before any conclusions on the zoological position or the function of conodonts can be formulated, it is necessary to ascertain just what types of fossils are to be included under the term "conodont." Obviously, the best source to consult is the original definition of the term that appears on pages 5 and 6 of Pander's (1856) monograph. From the literature it is quite evident that the original definition has not been accessible to all workers; hence a translation of Pander's definition by Mr. Ayvazoglou is here included.

> Minute fossils that closely resemble fish teeth in external form, lustrous, elongated, sharply pointed upward or toward one of the extremities, gradually or rapidly expanded downward, more or less bent, and usually provided with sharp edges, one anteriorly, the other posteriorly. The lateral faces are very differently shaped, being symmetrical or asymmetrical, plain or lined along their length, and often having a carina projecting laterally from their smooth surface.
>
> As in all teeth, a point and a base can be distinguished. The point is solid and the base hollow, forming the *cavitas pulpae.* The latter is differently shaped in the various types of conodonts. Usually the *cavitas pulpae* is rounded off in its upper part, often it becomes narrower, and sometimes it terminates in a blind point. . . . In most cases the upper solid end of the tooth is merely the gradual sharpening of the hollow base, but frequently the base is separated externally from the point by a constriction on the outer and inner borders or on the inner border only. The base, in some teeth, is extended at the lower borders of the tooth points in the same direction that the tooth is inclined, without causing much change in the outline of the latter [Pander cites *Oistodus* as an example]; . . . in

other cases this extension increased along a horizontal line [Pander cites *Prioniodus*]; . . . or in an inclined or vertical line [Pander cites *Cordylodus*]. . . . From this lateral elongation of the hollow base short and successive continuations are formed, which rise vertically, . . . obliquely, . . . or horizontally. . . . The many short additional denticles originated from these extensions. The compound teeth were formed in this manner. There can be no doubt that the hollow base was occupied by a pulp, and that a simple pulp formed a simple tooth and a compound pulp, a compound tooth.

The seeming slight change that conodonts have undergone is remarkable, for apparently their luster, color, and probably also their chemical composition are original, so that one might be tempted to ascribe them to the still living fishes. This complete preservation is also surprising, because these teeth can be traced from the oldest formations, the black slates, through all of the Lower Silurian formations up into the Devonian limestones, that is, conodonts are found in beds that have entirely different chemical compositions and that certainly passed through manifold chemical changes. It is all the more striking that this substance appears to consist almost entirely of calcium carbonate, for, upon solution in acids, carbon dioxide is released, and the oxalates produce a very considerable precipitate.

The different substances of conodonts can be divided into three classes. These classes are based upon the external appearance and the more or less conformable internal structure: (1) snow-white, opaque, with translucent borders; . . . (2) yellow, entirely translucent, and appearing hornlike; . . . and finally (3) white-reddish, compact, and entirely opaque. . . .

We must admit that the white ones mentioned by us under number (1) were, during the early stages of their ontogeny, yellowish and transparent and became snow-white and opaque only at maturity. Therefore, taking the substance into consideration, we might conclude that those placed in the second category are the young of the first. This viewpoint, however, must be discarded, because not only are the mature forms of the second category the most numerous of all of the teeth found, but also they constantly differ from those in the first category by having a long, hollow base. The white-reddish, completely dull, opaque forms are, as we shall see later, different in every respect from those in the first two categories.

PREVIOUS DISCUSSIONS OF NATURE OF CONODONTS

Answers to the question, What are conodonts?, have been numerous and varied, as witness the conclusions of authors in any summation of the literature. Briefly stated, it can be said that at one time or another conodonts have been considered to belong to organisms allied with such diverse groups as the Vermes, Mollusca, Arthropoda, primitive Vertebrata, and Pisces; and as having functioned as spines, dermal plates, filtering appendages, and teeth and other ingestive aids. Apparently there has never been unanimity among students of conodonts, and many diverse views can be found in even the recent literature on the subject. Schmidt (1934) and Demanet (1939) state that at least some of the conodonts functioned as the filtering appendages of fishes. The great majority of recent students, however, are agreed that conodonts were ingestive in function, but on the subject of zoological affinity their views differ widely. For example, Loomis (1936) prefers the gastropods; Scott (1934), the worms; Branson and Mehl (1933), the primitive fishes; and Stauffer (1938) suggests the primitive vertebrates. All these diverse views, however, have this in common. They are based primarily upon analogies of external form and very little, if at all, upon a consideration of the internal structure.

Evidently, then, it would appear, since so many propositions have been advanced and none have been acceptable to all, that a further study of the structure of conodonts is necessary before these fossils can be compared successfully with the anatomical parts of other animals. The prime purpose of the present paper is, therefore, to record through photomicrographs, as a contribution to the record, the morphology of certain conodonts.

First, however, it is desirable to review what Pander (1856) has already recorded. On pages 6 to 8 of the original publication on conodonts, he discussed the microstructure of these fossils at considerable length. Mr. Ayvazoglou's translation of this part of the article follows:

We shall turn now to the structure of these teeth, which structure departs from any that up till now had been considered indicative of ichthyological character, and which principally supplies the reason for not considering these remains to be fish teeth.

We have seen that so far as the base is concerned, it is hollow and was occupied by a pulp. From the surface of this pulp, which persisted for a long time, the substance of the wall of the pulp and of the tooth point was formed in such a way that one lamella after another was deposited. A lamella formed subsequently was placed against the inner wall of that which was formed previously. From these cones, which are differently

shaped, which lie one over another, and from which the name conodonts originated, one can obtain the clearest picture of the surface of the pulp during the formation of every single lamella. If we compare the shape of the pulp cavity in a conodont with that in a mature tooth, we see great differences insofar that the pulp cavity of a conodont does not extend very far up into the point. Thus it does not resemble the external form of the conodont as do the cavities in the teeth of most living fishes.

The successive formation of the lamellae can be clearly seen in the yellowish, transparent, flexible, hornlike teeth, especially when both surfaces of these teeth are slightly polished. It is much more difficult to observe the lamellar formation in the white, opaque teeth, which break easily owing to their brittleness. Since they are opaque, a much higher polish is required, and therefore they must be handled very carefully. A magnification of 100 diameters is sufficient to distinguish the concentric lamellae in both types; . . . and it seems that even at 300 diameters the yellowish types do not show anything more than homogeneous cones laid one upon another. . . . In the white types, the lamellae, or, more exactly, the spaces that lie between the cones, which alone we really see, are, instead of forming continuous interspaces, dissolved into small cells or bubbles, which are arranged regularly side by side along the length of the tooth.

In addition to the small cells discussed above, we see in the white teeth some other corresponding cells or cavities which are oval, larger, and distributed without any regular order. In general, they have their long axes parallel with the long axis of the tooth.

In the compound teeth . . . we could observe the cellular formation of the lamellae only in the large cusp and in the apical denticle, whereas in the denticles we observed only cells which, apparently, are distributed close to one another or above one another. . . . In the structure of the white-reddish, compact, opaque, mostly compound teeth, we have found a structure that was not clear to us, and therefore we have described it as we have seen it. It seems that their genesis from the surface of the pulp follows some other laws, which are still of a puzzling nature to us, namely: If we rub off both side surfaces, we find in the central plane, . . . at low magnifications, only alternating light and dark cross-striped areas, which are differently colored and pass from one rim of the tooth to the other. If a highly polished surface is studied at 300 magnification, the dark stripes appear to be composed of small cells or cavities, whereas the light stripes represent the homogeneous, transparent basic substance.

Although the base is hollow and in most cases has smooth walls, at times one finds in this area little dark grains or cavities of various sizes, with a dark border. . . .

Nothing can be said concerning the manner of attachment or the position of these teeth, because we did not find them attached to hard parts. We can maintain, however, with reasonable certainty, that these teeth were inserted into the mucous membrane of the throat, similar to the teeth of the cyclostomes and the squalids, but we were unable to determine which of the teeth belonged to the jaw, which to the lips, the tongue, or possibly to some other part of the palate.

Among the many thousands of teeth that we studied with the aid of the magnifying glass and microscope we know of only three in which a disarrangement evidently occurred during their growth. . . . In all three the original lamellar formation began regularly at the point but was interrupted sooner or later. . . . This first stage, which did not advance farther, remained clear and transparent, while the structure of the lower part of the tooth which was formed subsequently progressed together with the base and became entirely cellular.

Pander next notes the faunal association of conodonts with undoubted fish remains and after comparing the structure of conodonts with that of fish teeth concludes on pages 18 and 19 that:

A systematic classification of conodonts is very difficult. Not only are we completely ignorant of the animals that possessed the Lower Silurian teeth, but also there are no descendants or living animals that have a similar type of tooth structure. We do not know what kind of teeth we are investigating, whether they belong to the jawbone, the palate, or the tongue. Moreover, we do not know whether each special form may serve as a sufficient foundation for the erection of a specific category, or whether the various forms originated from the same animal. Judging by the laborious investigations made so far, we must abandon hope of finding some other hard parts of the same animals. For these reasons the classification of conodonts will always remain precarious and quite arbitrary.

But, based on the internal structure, we may still establish two main classes of conodonts: The first class, the *lamellar teeth*, includes those teeth that consist of cones arranged in layers, one above the other, and nearly parallel to the external periphery of the tooth. This class has many representatives in the older periods. The second class, the *obliquely layered teeth*, includes those teeth in which the lamellar structure cannot be seen. These teeth are denser and apparently consist of alternating cellular and noncellular layers, which form the structure of the tooth by lying obliquely one over the other.

Simple and compound teeth are found in both classes. The simple teeth can hardly be separated from the class of lamellar teeth, for relatively few of them are obliquely layered. . . .

There are great numbers of simple and compound teeth in the first class. So far, the simple teeth have been found only in the lowest Silurian formations; the compound teeth, on the other hand, pass from these beds through the Upper Silurian and Devonian formations into the Mountain limestone.

There is not sufficient reason for us to erect a

classification of these teeth that is based upon external form, that is, whether the teeth are straight or bent, crooked or inclined. Perhaps this feature can be used as an aid in determining species, but even here we had to be very cautious.

We found it more important to take into consideration the outlines we obtained by sectioning teeth through their middle part; for it can hardly be expected that smooth, ribbed, keeled, and truncated teeth could all exist in the mouth of the same animal.

Considering the equipment available to him, it is remarkable that Pander was able to present such a clear picture of the morphology of his conodonts. He, like so many others, was impressed by the great similarity of external form that exists between authentic teeth and conodonts. For this reason he found it difficult to explain the structural differences that exist between the two groups.

Furnish (1938) has recorded several observations on the morphology of conodonts. He writes:

> Pander's illustrations clearly show the growth lamellae present in typical conodonts. In distacodids, growth took place radially from what is now the tip of the basal cavity. The tooth must have started as a minute cap, which was extended upward to form the cusp, and down and outward to form the flangelike base enclosing the basal cavity.

In the same paragraph, Furnish suggested that

> Compound teeth apparently do not differ greatly from the distacodids in their method of growth; denticles are added posteriorly during ontogenetic development, and as they grow upward from the bar a trace of the point remains, extending down into the bar

as a growth axis.

TERMINOLOGY

As the assumption has existed since the beginning of the study of conodonts that these fossils functioned as ingestive aids, there has resulted the general adoption of a descriptive terminology that is highly suggestive of teeth and other mouth parts. For example, it includes such terms as "pulp cavity," "aboral side," "oral side," "cusp," and "denticle." This traditional terminology is serviceable and is used herein, but in so doing the author does not imply that the like-named parts of conodonts and of ingestive aids had similar origins or identical functions. For convenience the writer has also adopted a division of the conodonts into three groups depending upon the relative complexity of their growth patterns. These categories are: (a) the distacodid or simple cone-shaped type; (b) the compound type, characterized by denticulated blades and bars; and (c) the platelike type, distinguished by either lateral platforms or expanded pulp cavities. In the discussion of the compound and platelike conodonts, "transverse" is used to describe a section normal to the direction of most active growth; "longitudinal" to describe a section normal to the oral surface and parallel to the anterior-posterior direction; and "horizontal" for a section parallel to the oral surface.

MICROSTRUCTURE OF CONODONTS

The distacodid type.—The simplest types of conodont structure are those found in the distacodids. This group is confined to the Lower Paleozoic and has not been studied by the writer, information concerning it having been taken from the writings of Furnish (1938) and Pander (1856). Furnish, whose statements are quoted on this page has shown that the uniaxial growth of the distacodids resulted in the formation of toothlike forms, in each of which, as a consequence, the lamellae assumed a cone-in-

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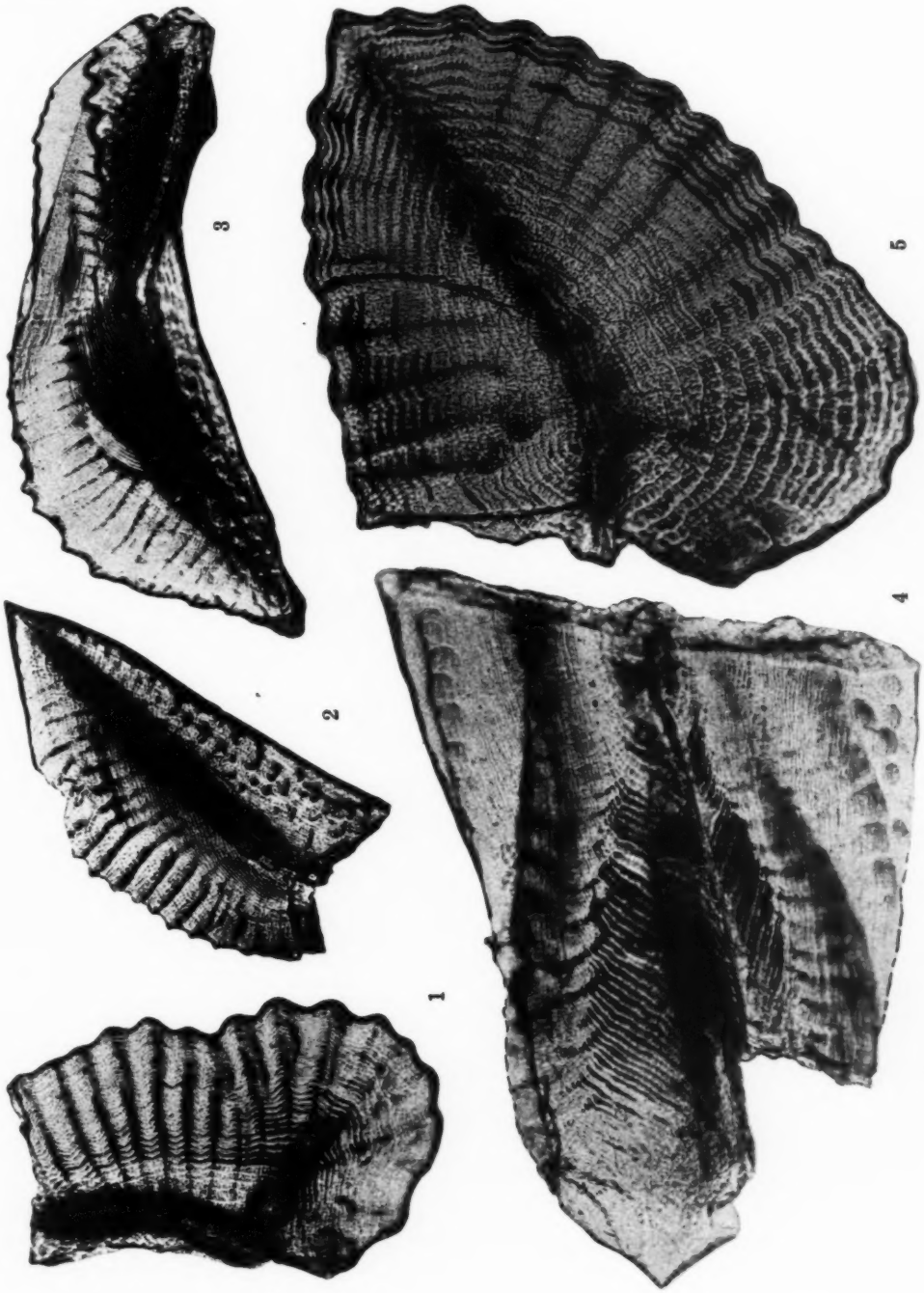
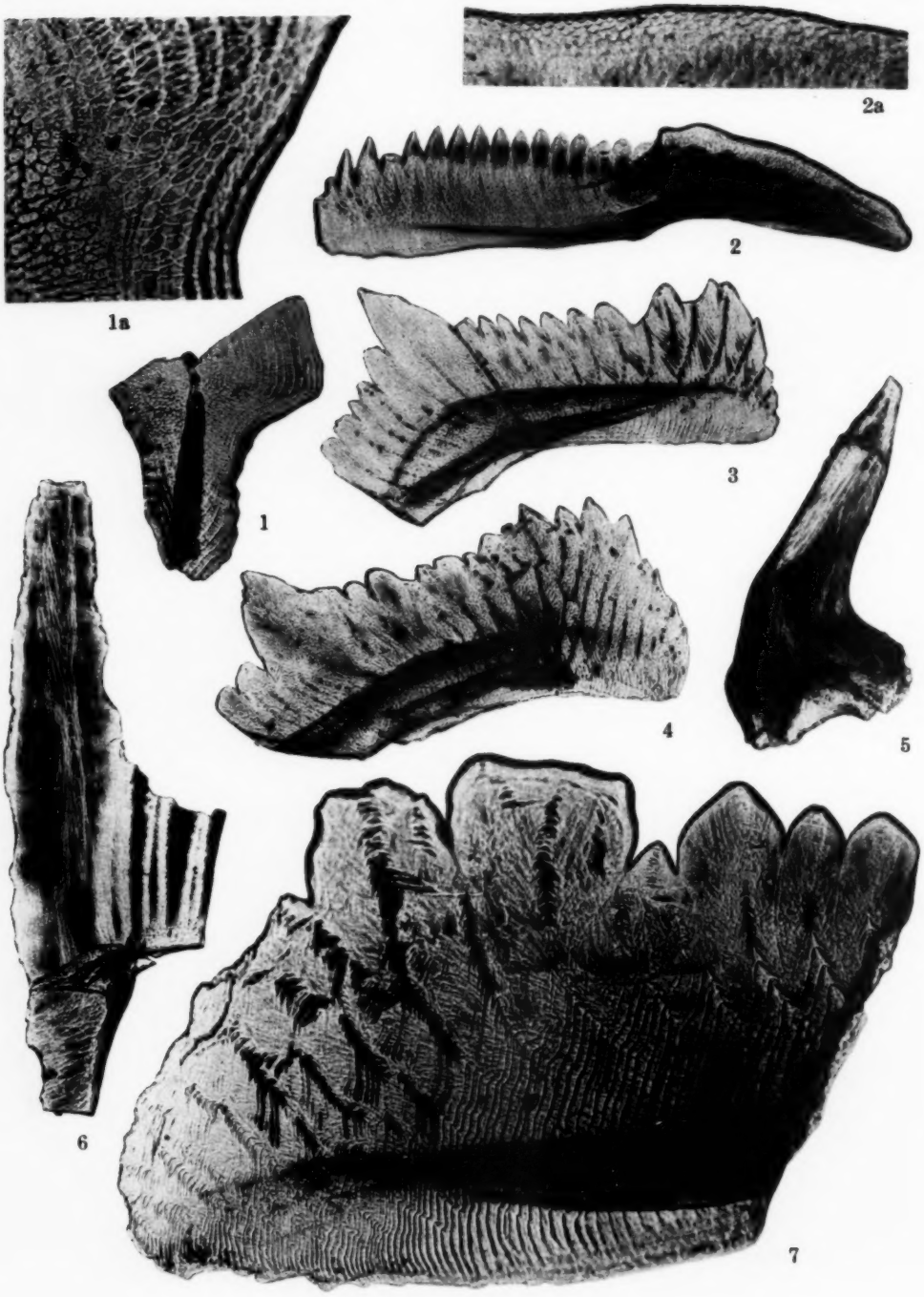
EXPLANATION OF PLATE 12

All specimens figured on this plate were photographed in transmitted light. The locality for all is a "Bushberg-Hannibal" horizon, south of Ada, Okla., in railroad cut, sec. 27, T. 3 N., R. 6 E.

FIGS. *1–5*—*Siphonognathus*. *1*, Horizontal view, fragment of plate showing suppression of parts, Geol. Survey 7536, ×65. *2*, Horizontal view, plate showing rejuvenation of parts, Geol. Survey 7537, ×65. *3*, Horizontal view of aboral surface showing concentric arrangement of lamellae about pulp cavity, and axial growth in platforms, Geol. Survey 7538, ×65. *4*, Horizontal view, rostral fragment showing concentric arrangement of lamellae, and axial growth in blade and rostral ridges, Geol. Survey 7539, ×120. *5*, Horizontal view, plate showing concentric arrangement of lamellae about pulp cavity, and axial growth of platforms. The oblique lines in the central part of figure are the free edges of the lamellae on the aboral side of the specimen, Geol. Survey 7540, ×120.



Hass, Conodonts



Hass, Conodonts

cone relationship. Both Furnish and Pander have illustrated the distacodid structure. Furnish's illustrations are line drawings in which the internal structure is indicated by a broken line connecting the tip of the pulp cavity with the apex of the conodont. This line, the growth axis, indicates the direction of most active growth. Pander's illustrations on the other hand, are figures in which the lamellae are indicated in section. One of his figures, that of *Oistodus lanceolatus*, is here reproduced as being typical of the distacodid group (pl. 15, fig. 1). In it, the laminated cone-in-cone structure as well as the extension and separation of each lamella along the growth axis is clearly but sketchily shown.

The compound and platelike types.—The compound and platelike conodonts differ from the distacodids only in that they exhibit a greater complexity of growth habit. In them, as evidenced by their lamellae, growth took place simultaneously in several directions and along many axes, instead of merely along one. Theoretically, then, since they had a less restricted mode of growth than the distacodids, the possible number of specific categories for them would be much greater; and, to judge by the literature, such is the case, for named compound and platelike species are legion. A few of these species are well represented in the material at hand, and even they show a wide diversity of form. But, to repeat, regardless of this external divergence, their internal structures show them to be merely variations upon a single theme. The very earliest stage in the growth of individual compound and platelike conodonts is represented, as in the distacodids, by a laminated cone-in-cone structure built up about the apex of the pulp cavity. In section, under high power, as witness plate 16, figure 1, these early laminations resemble curved, hairlike lines that extend upward from the sides of the pulp cavity toward the growth axis of the main denticle or cusp. This uniaxial mode of growth, however, was soon abandoned in favor of one that resulted in the genesis of the many compound and platelike forms.

In the compound conodonts the change to a polyaxial mode of growth resulted in the formation of denticulated blades and bars, and they as well as the anterior blades of the platelike conodonts have a structure similar to that found in *Solenognathus* (pl. 13, figs. 3, 4, 7), *Euprioniodina* (pl. 16, fig. 4), and the blade of *Gnathodus texanus* (pl. 15, fig. 4). In section, along the lines of most active growth each thin lamella or growth line originates at the aboral edge and continues to the center line of the denticle directly oral to its point of origin, where it assumes an angular or chevron shape in conforming to the outline of the denticle. Any growth line, moreover, is easily traceable from the basal part of one denticle into the denticle next closer to the pulp cavity, where, nearer to the apex, it again occurs as a chevron-shaped mark. Hence, it can be said that of any two adjacent growth lines the one that is farthest from the pulp cavity will approach nearer than the other to the apexes of the denticles into which they are traced. No growth line in the longitudinal sections cited above has been followed throughout its entire length, but the accretionary habit of the lamellae in any conodont can be inferred from the fact that regardless of the direction

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EXPLANATION OF PLATE 13

All specimens figured on this plate were photographed in transmitted light. The locality for all is a "Bushberg-Hannibal" horizon, south of Ada, Okla., in railroad cut, sec. 27, T. 3 N., R. 6 E.

FIGS. *1, 1a—Siphonognathus. 1*, Horizontal view, young specimen with widely spaced growth lamellae, Geol. Survey 7541, ×65. *1a*, Enlargement of *1*, showing polygonal network on oral surface of specimen, ×255.

2, 2a—Polygnathus. 2, Longitudinal view of a typical platelike conodont having lateral platforms, Geol. Survey 7542, ×65. *2a*, Enlargement of *2*, showing pitted oral surface of platforms, ×255.

3, 4, 7—Solenognathus. Longitudinal views showing aberrant effects due to suppression and rejuvenation of parts. *3*, Geol. Survey 7543, ×65; *4*, Geol. Survey 7544, ×65; *7*, blade fragment, Geol. Survey 7545, ×255.

5—Trichognathus. Longitudinal view of cusp showing rejuvenation, Geol. Survey 7546, ×65.

6—Prioniodus. Longitudinal view showing effects of obstruction of light rays by cellular structure, Geol. Survey 7547, ×65.

in which a thin section may be cut, the growth lines always have the same concentric relationships. This fact is clearly illustrated by the thin sections on plate 14, figure 6 and plate 16, figures 2, 5. These sections are in directions normal to that of most active growth, and it is to be noted especially that in the transverse sections (pl. 16, figs. 2, 5) each concentric growth line terminates aborally on both sides of a more or less centrally located zone. The character of the interlamellar areas is also plainly illustrated by the blade of *G. texanus* (pl. 15, fig. 4) and the above mentioned transverse sections. These interlamellar areas parallel to the directions of most active growth are in the thin sections tubelike, being hollow or but slightly filled with structural material. They are open at the aboral edge, and those that record the earlier stages of the ontogeny may be more than 20 times as wide as the lamellae that they separate. In the directions of less active growth, however, as well as in the later stages of normal growth along any one axis, these interareas are narrow or missing, the lamellae then being quite compactly arranged.

Conodont evolution, as judged by the stratigraphic succession of morphologic types, evidently was directed toward an enlargement of the surface area, a trend which culminated in the formation of the platelike species. These species, which apparently represent the complex derivatives of several lines of evolution out of the compound conodonts, are characterized by having either lateral platforms or expanded pulp cavities. In the material at hand, *Polygnathus* (pl. 13, fig. 2) and *Siphonognathus* (pl. 12, figs. 1–5) are characteristic of the first group, whereas the horizontal section of *Cavusgnathus* (pl. 14, fig. 6) is representative of the second. The extension and separation of the lamellae along the lines of most active growth are clearly seen in most of these figures, and it is to be noted, moreover, that such features as nodes, ridges, and even the platforms with their crenate margins are the direct result of axial growth. However, such features as the polygonal network of *Siphonognathus* (pl. 13, fig. 1a) and the pitted surface on the platform of *Polygnathus* (pl. 13, fig. 2a) are perhaps better explained as duplicating surface features of the tissue that covered the conodont.

In a few of the platelike species the platforms or the expanded pulp cavity extend throughout the entire length of the fossil, but most species, including those mentioned above, have these characters limited to the posterior part, the anterior part remaining much like the blade of a compound conodont. Although the lamellae of the platelike conodonts are extremely complicated, they differ only in degree from those already described, and they need not, therefore, be treated in detail. The mode of growth in those platelike conodonts that are characterized by lateral platforms is well illustrated by *Siphonognathus* (pl. 12, figs. 1–5; pl. 16, fig. 5). In the views on plates 12 and 16 each concentric lamella incloses all of the previously deposited ones about a central point, the pulp cavity. These lamellae are bent back upon themselves so as to approach the midline of the aboral side (pl. 16, fig. 5) and only in this respect do the platelike conodonts with lateral platforms differ greatly from those with expanded pulp cavities. For in the latter group the lamellae are not bent back upon themselves, but rather the free edge of each succeeding lamella advances aborally past the free edges of all previously accreted lamellae. This mode of growth resulted in the formation of an expanded pulp cavity.

The aboral side.—Owing to its accretionary mode of growth, a conodont could have been attached to another structure only along its aboral side. This possibility, moreover, is quite likely, for occasionally specimens are found with a foreign substance adhering to the aboral side. The writer has not studied this foreign substance, but they who have consider it to have functioned as the base to which the conodont was attached. The nature of this basal substance, however, is still problematical. It has been described by Kirk (1929) as a bony plate; by Branson and Mehl (1933) as being bony in appearance, but lacking in the ordinary structure of bone; and by Stauffer and Plummer (1932) as being either cartilaginous, or, like the conodonts, composed chiefly of a phosphatic carbonate of lime.

Be this as it may, the aboral side of any conodont is merely the zone of termination

for the free edges of its lamellae; and from this it would follow that the topography of the aboral side of any conodont is directly dependent upon the relative positions that these free edges maintain toward each other. In general terms there are three intergrading types of aboral sides—concave, convex, and flat. If the aboral side of any conodont is concave, grooved, or flared, it is indicated that the free edge of each succeeding lamella advanced aborally past the free edges of previously accreted lamellae. If the aboral side is convex or sharply ridged, it is indicated that each succeeding lamella retreated orally away from the free edges of all previously accreted lamellae, and finally, if the aboral side is flat, then the free edges of each lamella neither advanced nor retreated perceptibly away from the free edges of all of the others. These generalizations can be verified by reference to the transverse sections on plate 16.

Rejuvenation of injured parts.—During growth the strength of any conodont quite naturally increased with each additional lamella, in fact, so much so, that usually the thinner extremities of a mature conodont were the only parts ever broken away (see plates, especially *Solenognathus*, pl. 13, figures 4, 7; *Trichognathus*, pl. 13, figure 5; and *Lonchodus*, pl. 14, figure 1). These same figures, moreover, show that conodont-bearing organisms were capable of rejuvenating the lost parts of these structures or, rather, of rebuilding the structures up to normal size through a localized extension of the growth lamellae along one or more axes. The growth axes, so formed, were often out of alignment with the original axes upon which they were superimposed, a feature which resulted in a slight alteration of the shape of the affected conodont. Often a conodont underwent several such restoration of parts, and this, at first glance, appears to have done more than merely increase the structural complexity of the fossil. However, inspection shows that the fundamental accretionary plan upon which all conodonts are built was not abandoned in the process of rejuvenation, for lamellae in the restored parts are easily traceable into undamaged areas.

Occasionally, even the more massive parts of specimens were broken away, as witness the repairs to the cusp of *Trichognathus* (pl. 13, fig. 5) and the platform of *Siphonognathus* (pl. 12, fig. 2). Furnish (1938) in his paper on the Prairie du Chien conodonts records an even better example. He figures a specimen of *Drepanodus subarcuatus* which has the greater part of its cusp restored along an axis that is considerably out of alignment with the original axis.

Suppression of parts.—Although new growth axes, i.e., oral features, continued to appear throughout the ontogeny of any compound or platelike conodont, it was impossible in some specimens for all of these axes to develop into mature parts, the obvious reason being a lack of growing room. This condition resulted in the suppression of some of the axes in favor of others. As recorded by the lamellae, suppression of parts in a conodont was accomplished by the better-developed axes crowding the smaller and the broken ones away from the oral edge so that growth along them ceased. Suppression of parts is illustrated by *Subbryantodus* (pl. 14, fig. 3), as well as by the other specimens mentioned below. Evidences of suppression are to be expected in any conodont characterized by closely spaced denticles. In the material at hand, a few instances of suppression have been observed among the platelike forms (*Siphonognathus*, pl. 12, fig. 1), but the great majority of specimens that show this feature represent the compound bladelike types, such as *Solenognathus*, *Subbryantodus*, and *Hindeodella* (pl. 15, figs. 2, 3). Even though suppression was not limited to any one area of the specimen or stage of the ontogeny, it is, nevertheless, a common feature of the region adjacent to the pulp cavity, where the cusp or apical denticle is located. During normal growth in crowded surroundings this large denticle would of necessity incorporate within itself many of the smaller adjoining denticles. (See *Subbryantodus*, pl. 14, fig. 3.)

Unlike rejuvenation, suppression reduced the number of growth axes in a conodont and so, presumably, simplified the structure. But, like rejuvenation, it records the attempt of the conodont-bearing organism to maintain a maximum number of strong, effective axes along the oral surface of the conodont structure. Since this condition was met by each organism throughout its entire

ontogeny with an individual response, many aberrant forms of conodonts arose. The degree of aberration and the frequency with which such forms occur are great enough to warrant serious consideration in the delimitation of specific categories. (See *Solenognathus*, pl. 13, figs. 3, 4, 7.)

Effects due to lighting.—With respect to the transmission of light rays conodonts include all possibilities from transparency to opacity, the gamut being often observed in a single specimen. Since each lamella of a conodont is transparent and has merely a slight brownish tint, one would expect the depth of color in any specimen to be directly dependent upon the number of accreted layers, Moreover, the color of any specimen might be expected to increase gradually in intensity from the thin transparent extremities toward the apex of the pulp cavity, where the conodont would be least transparent. This, however, is not the case, for such a gradation of color in conodonts, as found fossil, is interrupted in several ways, among which are the following: Local concentrations of coloring matter, natural staining after the fossil was buried in sediment, weathering, and the obstruction of light rays by the internal structure of the conodont. To these, also, must be added the possibility that the amount of original coloring matter may have varied slightly with the individual or even with the stage of the ontogeny.

Two specimens were observed during the course of this study that showed a local concentration of coloring matter. One of these, a fragment of a blade, is illustrated on plate 14, figure 2. The irregular dark areas in this figure represent translucent amber patches in a transparent, brownish-tinted medium. Growth lamellae can be traced through some of these areas, but the relationships of these areas to the surrounding parts of the fossil could not be determined. As previously stated, the lamellae of any conodont are extended and separated from one another, along the directions of most active growth, the hollow interlamellar areas so formed being open along the aboral side. This structural feature gives free access for substances that might react with or stain the interior after the death of the conodont-bearing organism.

In some conodonts, especially those characterized by closely spaced denticles, the usual laminated structure of the growth axes is often obscured by a cellular or cancellate structure. Pander, who made this feature the basis for a major division of the conodonts (the obliquely laminated teeth), noted three types of cellular structure, the first and last of which are illustrated by *Prioniodus* (pl. 13, fig. 6). These types with reference to *Prioniodus* are: (a) the dissolution of the interlamellar areas of the cusp into "small cells or bubbles arranged regularly side by side along the length of the tooth"; (b) "cells or cavities which are oval, larger [than those mentioned under (a)], and distributed without a regular order, but in general having their axes" parallel to the

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EXPLANATION OF PLATE 14

FIG. *1*—*Lonchodus*. Longitudinal view, transmitted light, showing rejuvenation of parts, Geol. Survey 7557, ×100, from a "Bushberg-Hannibal" horizon, south of Ada, Okla., in railroad cut, sec. 27, T. 3 N., R. 6 E.

2—*Gnathodus*. Longitudinal view of blade fragment showing local concentrations of coloring matter, Geol. Survey 7549, ×55, from a "Bushberg-Hannibal" horizon, south of Ada, Okla., center NW ¼ sec. 2, T. 2 N., R. 6 E.

3—*Subbryantodus*. Longitudinal view of typical bladelike conodont showing rejuvenation of parts, Geol. Survey 7550, ×55, from a "Bushberg-Hannibal" horizon, south of Ada, Okla., center NW ¼ sec. 2, T. 2 N., R. 6 E.

4, 5—*Prioniodus*. *4*, Longitudinal view of typical compound conodont showing effect produced by reflected light, Geol. Survey 7560, ×55, from a "Bushberg-Hannibal" horizon, South of Ada, Okla., in railroad cut, sec. 27, T. 3 N., R. 6 E. *5*, Same specimen as *4*, transmitted light, ×55.

6—*Cavusgnathus*. Horizontal section of a platelike conodont with an expanded pulp cavity, showing the concentric lamellar structure running through areas of "alternating light and dark cross-stripes." Pander, not seeing the lamellar structure in his specimens, considered the "cross-stripes" of major importance. (See translation p. 73.) Geol. Survey 7561, ×100. From Barnett shale, in roadside ditch, 10.6 miles from Bend-Cherokee-San Saba cross roads on the Bend-San Saba road, San Saba County, Tex.

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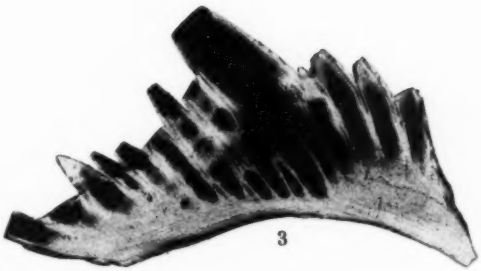

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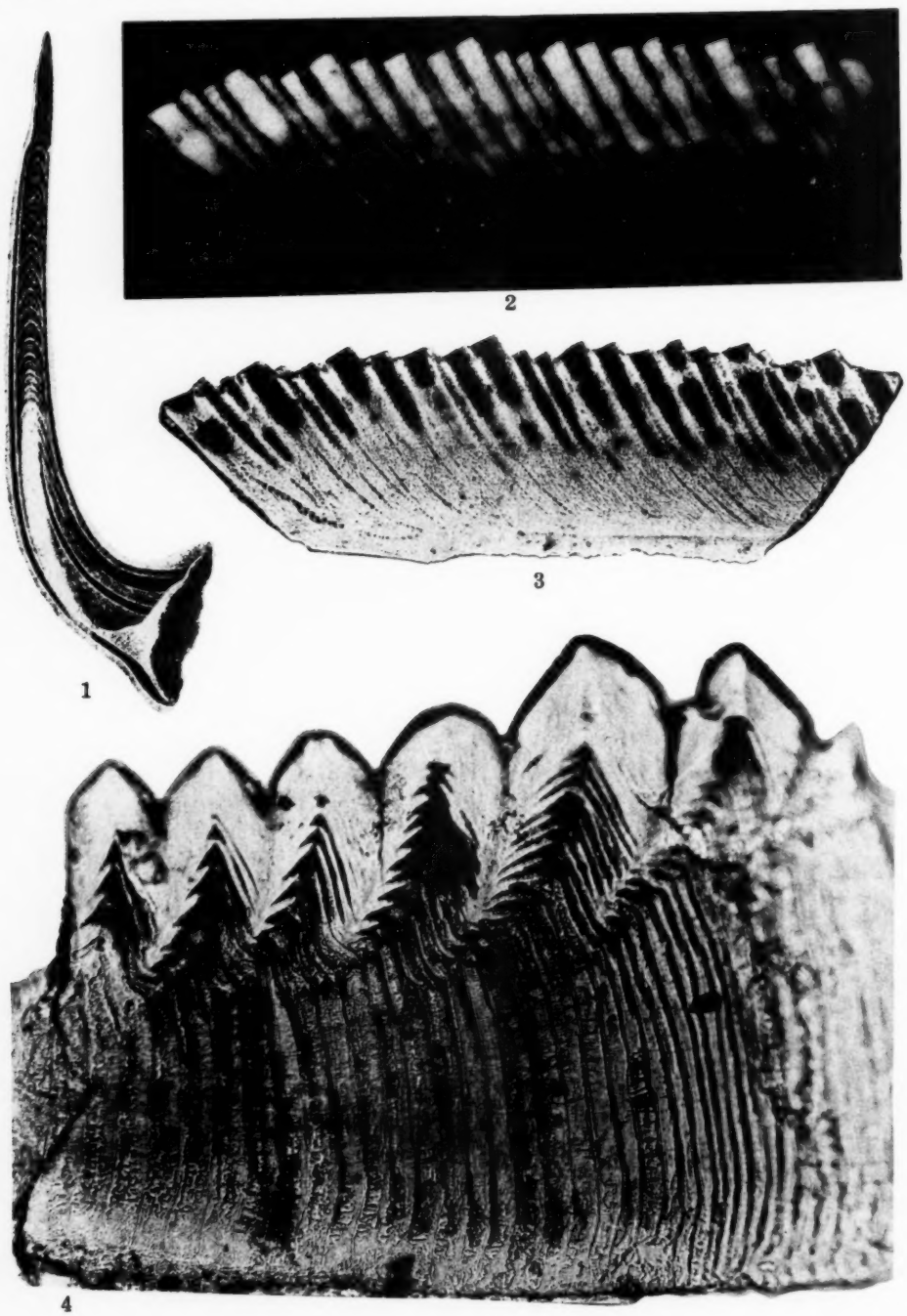
Hass, Conodonts



Hass, Conodonts

long axis of the cusp; and (c) the cellular structure of the denticles in which the cells are "close one to another or above one another." These types of cellular structure, because of their many surfaces, prevent the easy passage of light rays through a specimen, thereby causing a marked change in the appearance of a conodont when viewed alternately in transmitted light and in reflected light. These effects are shown by the figures of *Prioniodus* (pl. 14, figs. 4, 5; pl. 16, fig. 3), and of *Hindeodella* (pl. 15, figs. 2, 3; pl. 16, fig. 6). Under high power in transmitted light the denticles are seen to be composed of hollow spaces or tubules of differing size and shape. These tubules, which are layered and have their long axes arranged roughly in two directions, one parallel with, the other normal to the long axis of a denticle, give a cancellated appearance to that denticle. Often a denticle has several areas of cancellation along its length, between each of which a distinct laminated cone-in-cone structure is visible. These laminated zones, evidently rejuvenated parts, show conclusively that the fundamental laminated structure of conodonts was not abandoned during the formation of the cellular type of structure.

In reflected light, as witness the figures (pl. 14, fig. 4; pl. 15, fig. 2), conodonts take on an entirely different aspect, for in it the cellular or tubular structure cannot be seen. Rather, the cellular areas which in transmitted light were colored dark brown now appear white, and the previously transparent, brownish-tinted areas now appear black. Hence it is apparent that many of the "colors" of conodonts are the somewhat accidental effect of the manner of lighting. Cancellated denticles in reflected light appear peglike, and this feature has caused some authors to hold that such denticles are merely inserted into the basal part of the conodont bar, without being an integral part of it. The writer cannot accept this view, believing rather that the peglike appearance of the denticles represents the mass effects of the cancellated zones that impede the transmission of light sufficiently to obscure the primary lamellar structure of the denticle.

Summary of microstructure.—The present study shows that the distacodid, compound, and platelike conodonts are characterized by a laminated structure open toward the aboral side and built up about the apex of the pulp cavity by an accretionary process. The lamellae present in any conodont can be thought of as representing distinct growth stages in the ontogeny of that specimen. The first few growth stages of all conodonts were quite similar, their lamellae being not unlike a cone-in-cone structure; but after this early stage each species began to bear out its own ontogenetic pattern by concentrating its main growth along definite lines. In the distacodids, growth was along a single axis, whereas, in the compound and platelike forms it took place simultaneously in several directions and along many axes. The result of this directional growth in any specimen being that each additional lamella assumed more and more of the characteristic shape of the mature individual; or, stated somewhat differently, that a conodont species is a variable entity, the external forms of the specimens belonging to any one species being directly dependent upon the stages of ontogenetic development that they reached. In any conodont, the lamellae are extended along the lines of most active growth and are separated from one another by interlamellar areas. These areas, which are hollow or but slightly filled with structural material, are often, especially in the earlier stages of growth, more than 20 times as wide as the lamellae that they separate; but in the direction of less active growth, as well as in the later stages of growth along

EXPLANATION OF PLATE 15

FIG. *1*—*Oistodus lanceolatus* Pander. After Pander (1856, pl. 3, fig. 1, ×100), showing mode of growth in distacodid conodonts. Ordovician, Russia.

2, 3—*Hindeodella*. *2*, Longitudinal view of blade fragment, showing effect produced by reflected light, Geol. Survey 7535, ×65, from Barnett shale, 14 miles southeast of San Saba, Tex., on San Saba-Chappel road. *3*, Same specimen as *2*, transmitted light, ×65.

4—*Gnathodus texanus* Roundy. Longitudinal section of blade showing lamellar structure, Geol. Survey 7556, ×255, from Barnett shale, 3 miles southeast of San Saba, Tex., on San Saba-Chappel road.

any one axis, the lamellae are arranged more compactly, the interareas there being narrow or missing.

Because of the striking similarity in structure of the distacodid, compound, and platelike conodonts, it seems logical to conclude that they form a morphologic unit.

CLASSIFICATION OF CONODONTS

There can be no doubt that Pander intended to employ the term conodont for a morphologic group of laminated toothlike and platelike fossils. Though he accepted conodonts as fish teeth, he nevertheless was cognizant of their singular internal structure, a structure which he thought was built up by a pulp that occupied the interior of the organ. The writer does not subscribe to either of Pander's conclusions.

The reported finds of Scott (1934), Schmidt (1934), Demanet (1939), and others strongly suggest that certain conodont assemblages containing several nominal genera are natural associations of organs that belonged to one individual animal, that is, the nominal genera are not natural groups. Be this as it may, the writer is convinced that because conodonts are useful in stratigraphic paleontology, it is better to adopt a utilitarian classification based upon a similarity of form, and to leave for the future a classification more appropriate to pure zoology. All true conodonts, it has been shown, are characterized by a laminated structure that was built up about the apex of the pulp cavity; and this structural feature must form the basis of any morphologic classification, especially since these same lamellae record distinct growth stages in the ontogeny of a conodont. Usually the internal structure cannot be seen without the aid of thin sections, but this difficulty is overcome to a large degree by the fact that the exterior of any conodont merely records the last stage of the ontogeny that was reached before the death of the conodont-bearing animal. Therefore, the classification of Ulrich and Bassler (1926), or the more recent family groupings by Huddle (1934), both based on external form, can be freely used in indicating apparent morphologic relationships.

In any classification the pulp cavity is of prime importance, for not only is it a visible feature common to all true conodonts, but it is also the area about which the conodont was built. Hence, by using it as a reference point the various evolutionary trends out of the distacodids, through the compound, and into the complex platelike conodonts can be worked out.

The writer is firmly convinced that conodont species must be considered as entities that are quite variable in form, for in the erection of any species not only must the effects of suppression and of rejuvenation be taken into account, but also the stage of the ontogeny that was reached by any one specimen. Therefore, it seems safe to predict that a "telescoping" of numerous conodont species now recognized will be the next step in refining their use in paleontology. Of course, the extent to which this is done should be governed, at least in part, by utility. An example is the occurrence of the *Siphonognathus duplicata* = *S. quadruplicata* = *S. sexplicata* series in the Kinderhook. Branson and

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EXPLANATION OF PLATE 16

FIG. *1—Bryantodus.* Area of pulp cavity only. Longitudinal view, transmitted light, showing earliest laminations. Geol. Survey 7559, ×364, from "Bushberg-Hannibal" horizon, south of Ada. Okla., in railroad cut, sec. 27, T. 3 N., R. 6 E. (p. 75)

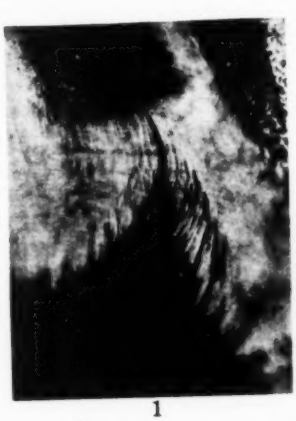
2—Lonchodus. Transverse section through *Lonchodus* type of fragment, showing concentric relationship of lamellae. Geol. Survey 7554, ×120, from Barnett shale, 3 miles southeast of San Saba, Tex. on San Saba-Chappel road. (p. 76)

3—Prioniodus. Enlargement of fig. 5, pl. 14, transmitted light, showing cancellated structure of denticles, ×255. (p. 79)

4—Euprioniodina. Longitudinal view, transmitted light, a typical barlike conodont. Geol. Survey 7558, ×65, from a "Bushberg-Hannibal" horizon, south of Ada, Akla., in railroad cut, sec. 27, T. 3 N., R. 6 E. (p. 75)

5—Siphonognathus. Transverse section through rostral area showing concentric relationship of lamellae, Geol. Survey 7553, ×120, from a "Bushberg-Hannibal" horizon, south of Ada, Okla., in railroad cut, sec. 27, T. 3 N., R. 6 E. (p. 76)

6—Hindeodella. Enlargement of anterior part of fig. 3, pl. 15, transmitted light, showing cancellated structure, ×225. (p. 79)



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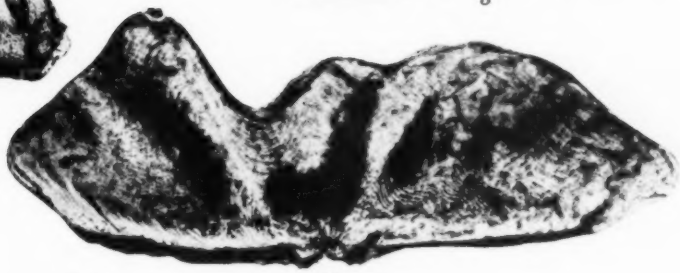

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Hass, Conodonts

UNIV. OF MICH.

Mehl (1934) have stated that in Missouri presumably only the first two members of this series are found in the Hannibal shale, whereas all three are found in the Bushberg sandstone member of the Sulphur Springs formation. Although the detailed field relationships of Branson and Mehl's collecting localities are not known to the writer, the method of growth in conodonts would suggest that beds lacking *S. sexplicata* are stratigraphically older than beds containing this fossil.

NATURE OF CONODONTS

As previously stated, the most general belief as to the nature of conodonts has been that they were the teeth or other ingestive organs of some marine animal. However, the fact that conodonts could be broken and subsequently repaired casts much doubt upon this assumption. There is no conclusive method of distinguishing between a mature and a large immature conodont, but if conodonts were ingestive aids, it is quite obvious from their structure that they could have functioned as such only after they were completely formed and had erupted as mature organs from the secreting medium. Subsequent to eruption, the only change that conodonts could have undergone would have been of a negative character and would have resulted from the wearing away of the structure through use. The writer has never seen a conodont so worn that its condition could be interpreted only as having resulted from use. On the other hand, numerous conodonts at all stages of growth clearly show that parts of their structure were broken away and later restored. Naturally, a rejuvenation of parts could have taken place only so long as the conodont was actually covered by a secreting medium, that is, at a time when the conodont was still unable to function as an ingestive aid.

In view of the various structural characters that have been described, it seems to the writer that the most logical interpretation that can be advanced is that conodonts functioned as the internal supports for tissues located at a place exposed to stress upon the exterior of or within the bodies of some genetically related group of marine animals.

CONCLUSIONS

In summary, the writer offers the following conclusions:

1. Because of their similarity in structure, conodonts are to be viewed as a morphologic unit.

2. The so-called species of conodonts are quite variable entities, the individual changing greatly in ontogenetic development.

3. Conodonts functioned as internal supports for tissues within or on the body of some marine organism at places subjected to stresses.

REFERENCES

BRANSON, E. B., and MEHL, M. G., *1933*, Conodont studies. Number 1: *Missouri Univ. Studies*, vol. 8, no. 1, p. 5.

——, *1934*, Conodonts from the Bushberg sandstone and equivalent formations of Missouri: *idem*, no. 4, p. 296.

DEMANET, F., *1939*, Filtering appendices on the branchial arches of *Coelacanthus lepturus* Agassiz: *Geol. Mag.*, vol. 76, no. 899, p. 215.

FURNISH, W. M., *1938*, Conodonts from the Prairie du Chien (Lower Ordovician) beds of the upper Mississippi valley: *Jour. Paleontology*, vol. 12, pp. 323–325, text fig. 1, p. 333.

HUDDLE, J. W., *1934*, Conodonts from the New Albany shale of Indiana: *Bull. Am. Paleontology*, vol. 21, no. 72, pp. 34–35.

KIRK, S. R., *1929*, Conodonts associated with the Ordovician fish fauna of Colorado—A preliminary note: *Am. Jour. Sci.*, 5th ser., vol. 18, pp. 495–496, figs. 1–14.

LOOMIS, F. B., *1936*, Are conodonts gastropods?: *Jour. Paleontology*, vol. 10, pp. 663–664, fig. 1.

PANDER, C. H., *1856*, *Monographie der fossilen Fische des silurischen Systems der russisch-baltischen Gouvernements*. St. Petersburg, 91 pages, 9 plates.

SCHMIDT, HERMANN, *1934*, Conodonten-Funde in ursprunglichem Zusammenhang: *Paleont. Zeitschr.*, Band 16, pp. 76–85, figs. 1–8.

SCOTT, H. W., *1934*, The zoological relationships of the conodonts: *Jour. Paleontology*, vol. 8, pp. 448–455, pls. 58–59.

STAUFFER, C. R., *1938*, Conodonts of the Olentangy shale: *Jour. Paleontology*, vol. 12, p. 414.

——, and PLUMMER, H. J., *1932*, Texas Pennsylvanian conodonts and their stratigraphic relations: *Texas Univ., Bull.* 3201, p. 22.

ULRICH, E. O., and BASSLER, R. S., *1926*, A classification of the toothlike fossils, conodonts, with descriptions of American Devonian and Mississippian species: *U. S. Nat. Mus., Proc.*, vol. 68, art. 12, pp. 1–63, pls. 1–11.

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FOUR NEW GENERA OF MISSISSIPPIAN CRINOIDEA INADUNATA

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FOUR Mississippian crinoid genera are here described. Of these, two, *Stinocrinus* and *Hylodecrinus*, are represented by species described for the first time. One genus, *Pelecocrinus*, has a range of known species from the Kinderhook to the upper Burlington, and *Cosmetocrinus* has known species ranging from the Kinderhook to the upper Borden. *Stinocrinus* is restricted to the New Providence, with a possible occurrence in the upper Borden, while *Hylodecrinus* is known with certainty only in the upper Borden, with a possible occurrence in the New Providence. A new family is proposed—Pelecocrinidae. The genotypes of all the genera are new species.

Family PELECOCRINIDAE Kirk, new family

Cyathiform to campanulate dorsal cup. Three anals in cup. Arms isotomous or endotomous. One or two *IBr* in all rays except anterior. Many *IBr* in ant *R*. Ventral sac moderately long, stout, reflexed, bringing the opening well down on the anterior side. Apex of sac tending to spinosity. Column stellate to pentagonal at least in proximal portion.

Contained genera.—Pelecocrinus, Abrotocrinus, Stinocrinus.

Genus PELECOCRINUS Kirk, new genus

Genotype, *Pelecocrinus insignis* Kirk, n. sp.

Crown: Expanding gradually to about one-third its height, then contracting. Bases of arms widely spaced and rami divergent, giving the arms a very open structure.

Dorsal cup: Campanulate.

IBB: Small, but showing plainly in lateral view.

BB: Large.

RR: Large. Articulating facet varying in width, one-half or more the width of the radial, at times reaching nearly the full width of the radial. Articulating face deep, with an inconspicuous transverse ridge and a shallow, subtriangular ligamental area. Facet horseshoe-shaped, directed somewhat outward.

IBr: One in all rays except anterior (two *IBr* rarely appear in one or two rays). In ant *R* there are usually 10 to 12 *IBr*, the series nearly corresponding in number and appearance with the *IIBr* in the other rays, with which it is probably homologous. The distal face of the IBr_1 of the ant *R* is transversely truncate.

Arms: The arms are long and relatively slender, having a length six times or more the height of the dorsal cup. There are usually two isotomous divisions above the dichotom. The divisions of the rami are widely separated as between adjacent rays and within an individual ray. This gives the crown a remarkably open appearance. The brachials show an unusual diversity in shape. In the proximal part of the arms a brachial from its pinnule-bearing face tends to contract slightly, then expand, then contract to a narrow face on the other side of the ramus. Some brachials fail to reach the far side. In the more distal part of the arms an almost biserial arrangement is sometimes seen. The pinnules are long and stout.

Post *IR: RA* is large, resting almost equally on the post and *r* post *BB*. It reaches about halfway the height of the *R*. Anal *X* is smaller and reaches approximately to the upper level of the *RR*. *RT* is still smaller and rises above the level of the *RR*. An abnormal specimen is figured (pl. 18, fig. 4) in which but one plate is present in the post *IR*.

Ventral sac: The ventral sac is approximately one-half the height of the crown. It is relatively slender and composed of 10 or more vertical series of plates. At the distal end five or more heavy spines are present, in the upper Burlington species at least. The ventral sac is a very incompetent structure and is usually found as a mass of disarticulated plates, the distal end being marked by the presence of the heavy spines.

Column: The column is pentagonal in outline in the proximal part, becoming circular

distad. The lumen is pentagonal. The columnals are low, with finely crenulate margins.

Geologic and geographic distribution.—The genus as known ranges from the Hampton to the "Burlington-Keokuk transition beds" of Iowa.

Relationships.—*Pelecocrinus* most nearly resembles *Abrotocrinus*. *Pelecocrinus* has a campanulate cup; horseshoe-shaped facets reaching but one-half to two-thirds the width of the *RR*; wide spacing of arms and rami with isotomous divisions and uniquely shaped arm ossicles; and a column that, although pentagonal in its proximal part, becomes circular a short distance distad. *Abrotocrinus*, on the other hand, has a bowl-shaped cup with depressed base; facets the full width of the *RR*; and fairly compact endotomous arms. The undescribed early species of *Abrotocrinus* in the Burlington are quite as distinct from *Pelecocrinus* as the Borden and Keokuk forms.

Remarks.—There seem to be three or more well-defined species of *Pelecocrinus* in the lower Burlington. Whether these can be accurately tied to the described species is not certain. Species have been made on dorsal cups and immature individuals, which makes accurate placement almost out of the question. The casual reference of almost all specimens from the lower Burlington to *P. aqualis* is particularly reprehensible. All we know of *P. aqualis*, practically, is that it is referable to the genus.

PELECOCRINUS INSIGNIS Kirk, n. sp.
Plate 18, figures 1–3, 5

This is by far the largest known species of *Pelecocrinus*. The crown of the holotype exceeds 14 cm. in height. The dorsal cup has an estimated maximum diameter of 3.5 cm. (uncrushed) and a height of 2 cm.

The dorsal cup is broadly campanulate in form. The plates are relatively thin. Low, broad, folds pass from plate to plate and at the apices of the plates are sharply defined depressions. The surface of the radial rises rather sharply toward the arm bases. The articulating facet is slightly crescentic, and the suture is somewhat gaping. The width of the facet on an average is about two-thirds the width of the radial, but the relative widths vary within the same specimen and between different specimens. The lateral shoulders of the radials are always of fair width, making for a considerable separation of the *IBr*.

The post *IR* is broad, the *RA* and anal *X* being of almost equal height and width. The ventral sac in the holotype has a height of not less than 7.5 cm., excluding the terminal spines. The terminal spines, five or more in number, are very stout and have a length of 1.5 cm. or more. They might easily be mistaken for *Dorycrinus* spines.

The arms divide by dichotomy twice above the main dichotom in all rays except the anterior. In the latter there is but one division above the main dichotom. The *IAx* are low. The *IIBr* number 10 or 11. In the ant *R* the *IBr* number 11 or more. The *IIIBr* series have at least twice as many *Br* as the *IIBr* series. The pinnules are long and stout.

The column is composed of thin columnals. The column is pentagonal in the proximal part but changes to circular in section within a short distance.

Horizon and locality.—All known specimens are from the upper Burlington "Burlington-Keokuk transition beds." The holotype is from the quarry at Ninth and Angular Streets, Burlington, Iowa. The other specimens probably came from the same quarry.

Types.—The types are in the Springer Collection, United States National Museum; holotype, S 4331a; paratypes, S 4331b and c.

Relationships.—*Pelecocrinus insignis* is the only described species from the upper Burlington. From all the lower Burlington species it differs in its much greater size, stouter arms, and more broadly campanulate cup.

PELECOCRINUS AQUALIS (Hall)

Poteriocrinus aqualis HALL, *1860*, p. 63, text fig. p. 63.

Poteriocrinus (*Scaphiocrinus*) *aequalis* (part) WACHSMUTH AND SPRINGER [error for *aqualis*], *1880*, p. 112 (335).

?Pachylocrinus aqualis SPRINGER, *1926*, p. 71, pl. 16, fig. 10.

"Burlington limestone, Burlington, Iowa." (Lower Burlington.)

PELECOCRINUS FISCELLUS
(Meek and Worthen)

Scaphiocrinus fiscellus MEEK AND WORTHEN, *1869*, p. 146; *1873*, p. 424, pl. 1, fig. 3.

Poteriocrinus (*Decadocrinus*) *fiscellus* WACHSMUTH AND SPRINGER, *1880*, p. 119 (342).

"Lower division of Burlington group, Burlington, Iowa."

PELECOCRINUS LEPIDUS (Hall)

Poteriocrinus lepidus HALL, *1861*, p. 304; *1861a*, p. 6. WACHSMUTH AND SPRINGER, *1880*, p. 120 (343).

"Burlington limestone, Iowa." (Lower Burlington.)

PELECOCRINUS PARVIGLYPTUS
(Laudon and Beane)

Abrotocrinus parviglyptus LAUDON AND BEANE, *1937*, p. 257, pl. 18, fig. 5 (holotype); pl. 17, figs. 14, 15 (paratype).

"Hampton formation, Le Grand, Iowa."

PELECOCRINUS SOLIDUS
(Meek and Worthen)

Poteriocrinus (*Scaphiocrinus*) *solidus* MEEK AND WORTHEN, *1861*, p. 140.
Poteriocrinus (*Scaphiocrinus*) *aequalis* Hall (part). WACHSMUTH AND SPRINGER, *1880*, p. 112 (335).

"Burlington limestone, Burlington, Iowa." (Lower Burlington.)

PELECOCRINUS TENUIDACTYLUS
(Meek and Worthen)

Poteriocrinus (*Scaphiocrinus*) *tenuidactylus* MEEK AND WORTHEN, *1865*, p. 156. MEEK AND WORTHEN, *1868*, p. 490, pl. 18, fig. 10, text fig.
Poteriocrinus (*Scaphiocrinus*) *aequalis* HALL (part). WACHSMUTH AND SPRINGER, *1880*, p. 112 (335).

"Burlington limestone, Burlington, Iowa."

Genus STINOCRINUS Kirk, new genus

Genotype, *Stinocrinus granulosus* Kirk, n. sp.

Crown: Medium height, compact, subcylindrical.

Dorsal cup: Cyathiform. Plates heavy, slightly convex.

IBB: Very small, barely showing in side view. The *IBB* in the type species are triangular in outline and do not meet laterally.

BB: Large.

RR: Large, articulating facet extending full width of *R*, slightly crescentic, with slightly gaping suture.

IBr: Heavy, in contact laterally except in post *IR*. *IBr* two in all rays except anterior. Here there may be as many as nine.

Arms: Stout, with highly rounded backs. In the anterior radius there is but one isotomous division as seen. In the other rays there is at least one isotomous division above the main dichotom. In one half-ray in the *1* post *R* there is a still higher division of the outer ramus, tending toward endotomy. The *IIBr* are numerous. The rami are in lateral contact within the ray and between the adjacent rays except in the post *IR*. Even here the *IIIBr* meet laterally.

Post *IR: RA* is elongate, pentagonal, and lies obliquely in the cup. It meets *r* post *R* on a relatively narrow face and the post *B* on a very long face. Anal *X* is small but rises well above the level of the *R*. *RT* is large and reaches well up on IBr_1.

Ventral sac: Unknown.

Column: Obscurely pentagonal in the proximal part, with a very small pentagonal lumen.

Geologic and geographic distribution.—So far as known, the genotype, the only species referred with certainty to *Stinocrinus*, is restricted to the New Providence of Kentucky. If *Scaphiocrinus manus* Miller and Gurley is a *Stinocrinus* (I have not examined its type), the genus is represented in the upper Borden of Indiana.

Relationships.—In common with many of the other New Providence crinoids, *Stinocrinus* shows no close relationships to known Mississippian forms. It perhaps resembles *Pelecocrinus* as much as any genus, and for this reason it is placed in this paper. The

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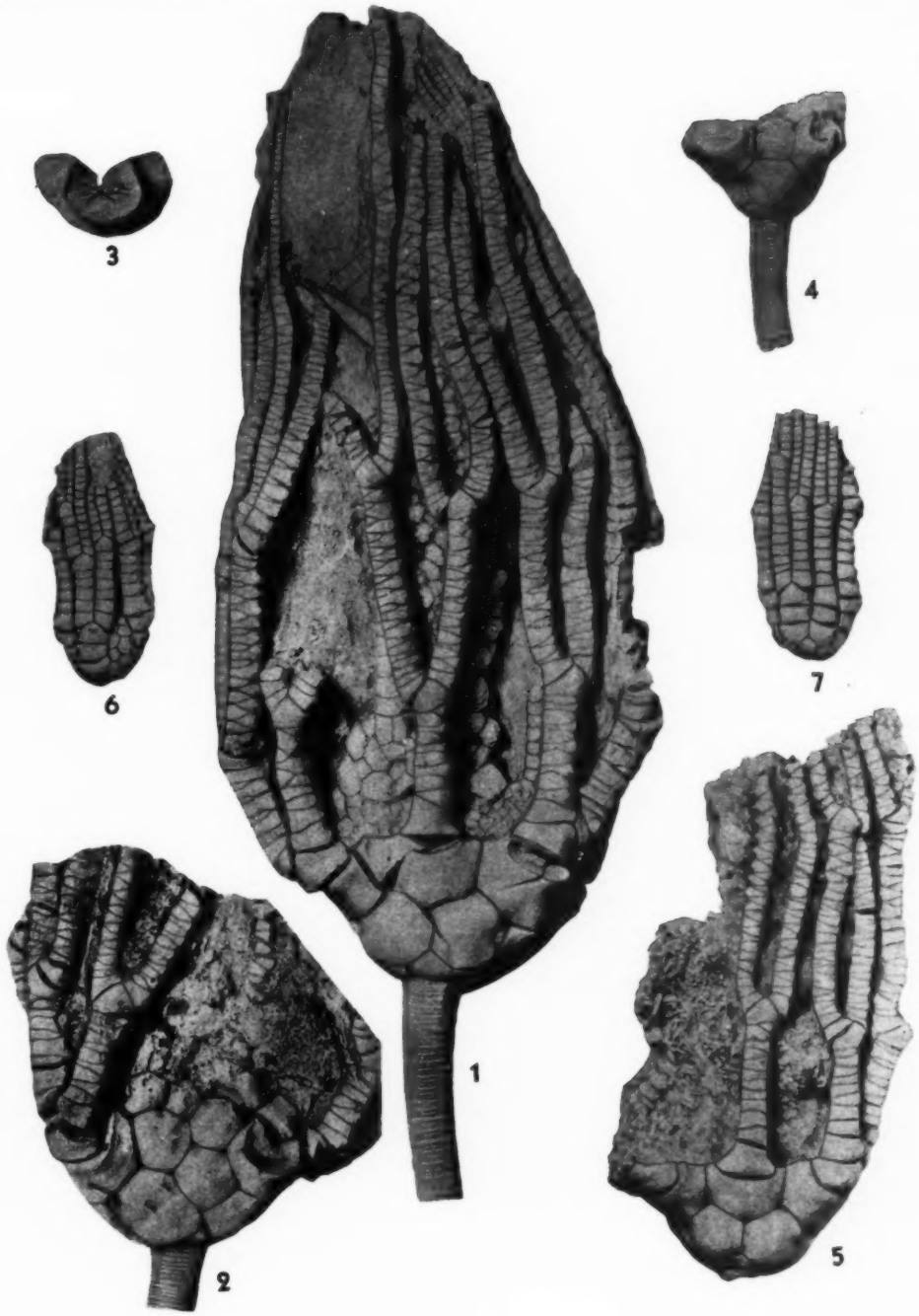
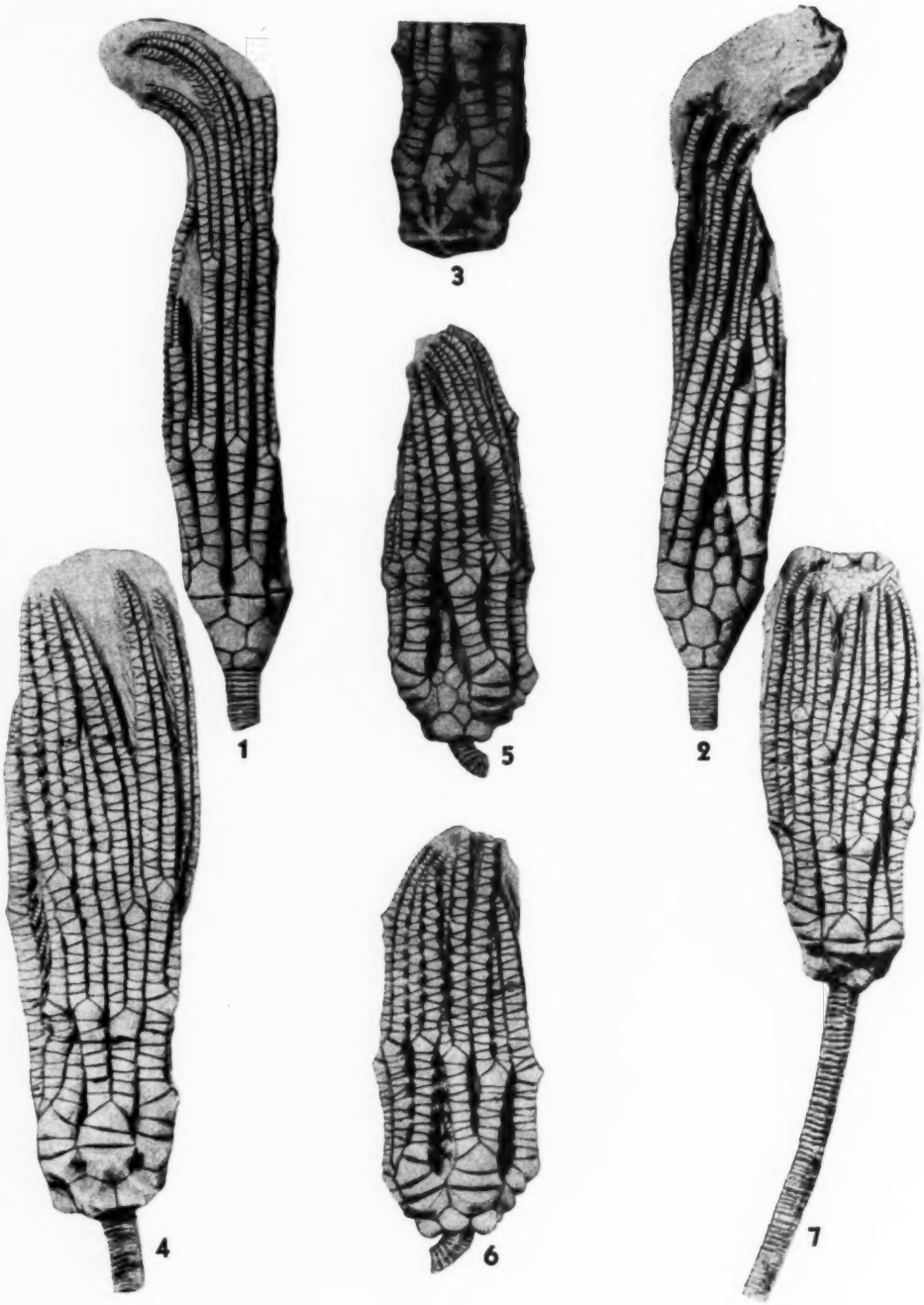
EXPLANATION OF PLATE 17
All figures natural size

FIGS. *1, 2—Cosmetocrinus gracilis* Kirk, n. sp. *1*, Anterior, and *2*, posterior, view of holotype. (p. 87)
3, 4, 7—Hylodecrinus sculptus Kirk, n. sp. *3*, Posterior, and *4*, anterior, view of holotype; *7*, right anterior view of paratype. (p. 86)
5, 6—Hylodecrinus asper Kirk, n. sp. *5*, Posterior, and *6*, anterior, view of holotype. (p. 86)



Kirk, Mississippian Crinoids



Kirk, Mississippian Crinoids

cyathiform cup is in marked contrast to the campanulate cup of *Pelecocrinus*, and the disposition of the plates of the post *IR* is quite unlike. The two *IBr* of *Stinocrinus* and the stout, laterally appressed arms are in marked contrast to the one *IBr* and widely separated arms of *Pelecocrinus*. The discrete *IBB* of *Stinocrinus* are a character found in very few genera.

STINOCRINUS GRANULOSUS Kirk, n. sp.
Plate 18, figures 6, 7

The species is based on a fairly complete crown and another crown with a partial set of arms. All measurements given are of the holotype.

The crown is compact, subcylindrical, with a maximum probable length of about 40 mm.

The dorsal cup has a height of 4 mm. and a maximum diameter of about 9 mm. The cup is smoothly rounded, cyathiform, and all plates are thickly covered with rounded granules.

There are two *IBr* in all rays except the anterior. There are nine *IBr* in the ant *R*. The number of the *IIBr* varies from six to 13. All *Br* are thickly granulose. Each axillary is tumid in its apical part.

Horizon and locality.—Both specimens are from the New Providence of Button Mould Knob, south of Louisville, Ky. The holotype was collected by Carl Rominger.

Holotype.—U. S. Nat. Mus. 37633.

Genus HYLODECRINUS Kirk, new genus

Genotype, *Hylodecrinus sculptus* Kirk, n. sp.

Crown: Compact, subcylindrical, arms approximately nine-tenths height of crown.

Dorsal cup: Cyathiform, with flattened base. Plates heavy, tumid.

IBB: Small, not visible in lateral view, practically covered by column.

BB: Large, forming base of cup as seen in side view.

RR: Large, arm facet full width of *R*; suture gaping.

IBr: Two in all rays.

Arms: Stout, endotomous, with two divisions above main dichotom except in ant *R*, where usually there is but one isotomous division above the dichotom. Axillaries nodose, and usually each *Br* has a small node, giving the crown a rough, uneven appearance. *Br* with slightly sloping faces. Pinnules long, stout.

Post *IR: RA* pentagonal, resting below almost equally on post and *r* post *BB*. *X* large, rising above level of *R*. *RT* reaching well up on *IAx*.

Ventral sac: Relatively slender, reaching to near tips of arms. Recurved. At the flattened apex is a cluster of small spines.

Column: Stellate in section in the proximal part, becoming pentagonal distad. Lumen pentagonal. Columnals low.

Geologic and geographic distribution.—The genus is known only from the upper Borden of Indiana, and perhaps the New Providence of Kentucky.

Relationships.—In general habit *Hylodecrinus* most nearly resembles *Pachylocrinus*. *Hylodecrinus* has stout arms with few divisions, a long ventral sac, and a column stellate in section in proximal part, changing to pentagonal farther distad. In a few species of *Pachylocrinus*, possibly founded on immature specimens, there are few arm divisions as in *Hylodecrinus*. The large group of species segregated as *Pachylocrinus* uniformly has a fairly low crown with slender arms and with three or more endotomous divisions. *Pachylocrinus* is consistently, so far as known, represented by relatively small individuals. The ventral sac of *Pachylocrinus* is relatively shorter than in *Hylodecrinus*. The column of *Pachylocrinus* may be obscurely pentagonal in the proximal part but is typically circular in section.

EXPLANATION OF PLATE 18

All figures natural size unless otherwise stated

FIGS. *1–3, 5—Pelecocrinus insignis* Kirk, n. sp. *1*, Anterior, and *2*, posterior, view of holotype, *3*, Anterior radial of a paratype, ×1¼. *5*, Anterior view of a younger paratype. (p. 83)

4—Pelecocrinus sp. Abnormal specimen with but one plate in post *IR*, lower Burlington. (p. 82)

6, 7—Stinocrinus granulosus Kirk, n. sp. *6*, Posterior, and *7*, anterior, view of holotype. (p. 85)

HYLODECRINUS SCULPTUS Kirk, n. sp.
Plate 17, figures 3, 4, 7

The species is represented by seven crowns. The longest complete crown has a height of 9 cm. There are two specimens whose dorsal cups are larger than this specimen.

The dorsal cup has a diameter about twice its height. The base is sharply truncate, and the walls diverge slightly to the arm bases. The cup plates are very heavy. The sculpturing of the plates of the dorsal cup is very characteristic and identifies the species at once. The *BB* are highly tumid. From the center of each basal, high ridges pass to the adjacent plates, outlining deep triangular depressions. Similar ridges pass from plate to plate in the posterior interradius, but these are less sharply defined.

The arms are long and stout, with long, stout pinnules. The arms are endotomous, with two divisions above the main dichotom. The admedian rami reach to the common distal extension of the arm group. In young to medium-sized specimens the ant *R* has but one isotomous division above the dichotom. In very large specimens another division occurs, giving an endotomous structure. The arms seem to have been unusually fragile, as three specimens show extensive regeneration in one or more rays.

Horizon and locality.—All specimens are from the upper Borden of Indian Creek, Montgomery County, Ind.

Types.—The holotype, U. S. Nat. Mus. S 2632a, and paratype, S 2632b, are in the Springer Collection.

HYLODECRINUS ASPER Kirk, n. sp.
Plate 17, figures 5, 6

This species is represented by a single remarkably fine crown, which has a height of approximately 6 cm.

The dorsal cup has a height about one-half the maximum breadth. The base is sharply truncate. The basals are highly tumid but devoid of ridges passing to adjacent plates.

The arms are stout and relatively short compared with *Hylodecrinus sculptus*. The arms are irregularly endotomous. In the anterior ray there is a single isotomous division above the main dichotom. The same structure appears in two half rays elsewhere and might appear in all rays.

Relationships.—Hylodecrinus asper may readily be distinguished from *H. sculptus*. The relatively shorter, stouter arms, the cup with more widely diverging sides, and the lack of radiating ridges on the cup plates give *H. asper* a quite distinctive appearance.

Horizon and locality.—Known only from the upper Borden of Indian Creek, Montgomery County, Ind.

Type.—The holotype is in the Springer Collection, U. S. Nat. Mus. S 4332.

Genus COSMETOCRINUS Kirk, new genus

Genotype, *Cosmetocrinus gracilis* Kirk, n. sp.

Crown: High, subcylindrical. Ratio of cup to height of crown about 1:10.

Dorsal cup: Subturbinate. Plates moderately thin, smooth.

IBB: Large, making up an appreciable amount of the dorsal cup wall.

BB: Large.

RA: Relatively small. Radial facet straight, or slightly crescentic, extending full width of *R*. Suture gaping.

IBr: One in all rays, elongate, constricted medially. Abnormally, probably as a result of regeneration, two *IBr* may be present.

Arms: Long, relatively slender. *Br* with sloping faces, approaching cuneate. In early species one isotomous division occurs above the dichotom. In later species both the rami of a half ray may divide, continuing the isotomous structure; the admedian ramus alone may divide; or the outer ramus alone may divide. The arms seem to have broken off easily, resulting in a considerable amount of regeneration. In some species, as *Cosmetocrinus indianensis*, this makes for very irregular branching of the arms. In some cases the $IIBr_1$ is axillary.

Post *IR: RA* is large, resting about equally on post and *r* post *BB* but not penetrating deeply between them. Anal *X* reaches well up on *IAx*. *RT* lies mostly above the level of *R*.

Ventral sac: Long, slender, composed of a few vertical series of relatively large plates.

Column: Circular in section, with a pentalobate lumen.

Geologic and geographic distribution.—The genus, as known, ranges from the Hampton

of Iowa through the Burlington of Iowa to the Borden of Indiana.

Relationships.—The species of *Cosmetocrinus* have been variously ascribed to *Poteriocrinus*, *Scaphiocrinus*, *Scytalocrinus*, or *Pachylocrinus*. *Scaphiocrinus* in the sense used here is nonexistent. *Poteriocrinus*, though much worked over, is still to be defined. According to my interpretation, *Poteriocrinus* bears no resemblance to *Cosmetocrinus*. The branching arms and the turbinate cup with large infrabasals at once separate *Cosmetocrinus* from *Scytalocrinus*. The long isotomous arms, turbinate cup, prominent *IBB*, and one *IBr* sharply differentiate *Cosmetocrinus* from *Pachylocrinus*.

Remarks.—*Cosmetocrinus gracilis* has been chosen as genotype because it is represented by the only complete crown known to me from the higher horizons. Many complete crowns of species in the Kinderhook and lower Burlington are available, but these, although referable to the genus, are very small and rather generalized in their structures.

COSMETOCRINUS GRACILIS Kirk, n. sp.
Plate 17, figures 1, 2

This is a relatively small species from the Borden, the crown measuring but 10 cm. in height. There is no reason to suspect that it is an immature individual, however.

The dorsal cup has a height of 10 mm. and a maximum diameter of about the same. The *IBB* have an average height of 3 mm., the *BB* 5 mm., and the *RR* 4 mm.

The *IBr* are high and constricted medially. The arms are long and relatively slender. In the left half of the *r* post *R* of the type the $IIBr_1$ is axillary, but this seems to be abnormal. In other half rays the number of *IIBr* ranges from 6 to 10. The irregular division of the arms characteristic of the later species of the genus is well shown in the type specimen. In most cases there are two isotomous divisions above the dichotom. In one-half of another ray the admedian ramus has a second isotomous division, but the other ramus remains simple. Several rami have been broken off and regenerated.

Horizon and locality.—The species is known only from the upper Borden of Indian Creek, Montgomery County, Ind.

Type.—The holotype is in the Springer Collection, U. S. Nat. Mus. S 4330.

Relationships.—*Cosmetocrinus indianensis* (Meek and Worthen) is practically unrecognizable from the figure and description. Other specimens from Crawfordsville indicate that it may be the same species as *C. crawfordsvillensis* (Miller and Gurley). It certainly is much like it. All specimens seen from Crawfordsville referable to *Cosmetocrinus* have a narrower, more elongate dorsal cup than *C. gracilis*. The infrabasals of *C. indianensis* are relatively higher, and the *IAx* is lower and broader than in *C. gracilis*. The presence of two *IBr* in the post *RR* of the type of *C. indianensis* may be considered abnormal, or an error of observation. The figure of *C. crawfordsvillensis* seems to show an atomous arm in the ant *R*, but the text definitely states that the first primibrach of this ray is axillary.

COSMETOCRINUS CRAWFORDSVILLENSIS (Miller and Gurley)

Poteriocrinus crawfordsvillensis MILLER AND GURLEY, *1890*, p. 23, pl. 4, fig. 8.

"Keokuk group, Crawfordsville, Indiana." (Upper Borden.)

COSMETOCRINUS CRINEUS (Hall)

Poteriocrinus crineus HALL, *1863*, p. 7; *1864*, p. 56; HALL AND WHITFIELD, *1875*, p. 172, pl. 12, figs. 6–7.
Poteriocrinus (*Scaphiocrinus*) *crineus* WACHSMUTH AND SPRINGER, *1880*, p. 112 (335).

"Waverly group, Richfield, Summit Co., Ohio."

COSMETOCRINUS DELICATUS (Meek and Worthen)

Scaphiocrinus delicatus MEEK AND WORTHEN, *1869*, p. 144; *1873*, p. 407, pl. 1, figs. 5a–b.
Poteriocrinus (*Scaphiocrinus*) *delicatus* WACHSMUTH AND SPRINGER, *1880*, p. 113 (338).

"Upper Burlington, Burlington, Iowa."

COSMETOCRINUS ELEGANTULUS (Wachsmuth and Springer)

Scaphiocrinus elegantulus WACHSMUTH AND SPRINGER, in Miller, S. A., *1889*, p. 279, fig. 424; WACHSMUTH AND SPRINGER, *1890*, p. 195, pl. 17, fig. 13.
Poteriocrinus legrandensis MILLER AND GURLEY, *1890a*, p. 39, pl. 7, figs. 4–6.
Pachylocrinus legrandensis LAUDON AND BEANE, *1937*, p. 256, pl. 18, figs. 3.

"Kinderhook beds, Le Grand, Iowa." (Hampton formation.)

COSMETOCRINUS INDIANENSIS
(Meek and Worthen)

Poteriocrinus indianensis MEEK AND WORTHEN, *1865*, p. 155. *1868*, p. 515, pl. 20, fig. 4.
Poteriocrinus (*Scytalocrinus*) *indianensis* WACHSMUTH AND SPRINGER, *1880*, p. 117 (340).

"Keokuk, Crawfordsville, Indiana."

COSMETOCRINUS MEEKI Kirk, n. name

Poteriocrinites (*Scaphiocrinus*) *nanus* MEEK AND WORTHEN, *1869*, p. 141. *1873*, p. 423, pl. 1, fig. 8.
Poteriocrinus (*Scaphiocrinus*) *nanus* WACHSMUTH AND SPRINGER, *1880*, p. 113 (338).
Not *Poteriocrinus nanus* Roemer, *1863*.

"Lower Burlington, Burlington, Iowa."
Type, 1421, Museum of Comparative Zoology, Cambridge, Mass.

COSMETOCRINUS RICHFIELDENSIS
(Worthen)

Poteriocrinus richfieldensis WORTHEN, *1882*, p. 15; *1883*, p. 285, pl. 30, fig. 5.
Woodocrinus richfieldensis WACHSMUTH AND SPRINGER, *1886*, p. 242 (166).

"Kinderhook group, near Richfield, Ohio."

REFERENCES

HALL, JAMES, *1860*, Contributions to the paleontology of Iowa; being descriptions of new species of Crinoidea and other fossils: *Iowa Geol. Survey*, vol. 1, pt. 2, Supplement (1859). Inserted unnumbered page, pp. 1–94, text figs., pls. 1–3.

——, *1861*, Descriptions of new species of Crinoidea from the Carboniferous rocks of the Mississippi Valley: *Boston Soc. Nat. History, Jour.*, vol. 7, pp. 261–328.

——, *1861a, Descriptions of new species of Crinoidea; from investigations of the Iowa Geological Survey. Preliminary notice.* Privately issued, Albany, N. Y., pp. 1–12, February 14; pp. 1–18 (complete paper), February 25.

——, *1863, Preliminary notice of some species of Crinoidea from the Waverly sandstone series of Summit County, Ohio, supposed to be of the age of the Chemung group of New York*, pp. 1–11. "Printed in advance, from the 17th Report on the New York State Cabinet, James Hall. Albany, published November 11, 1863."

——, *1864*, Preliminary notice of some species of Crinoidea from the Waverly Sandstone Series of Summit County, Ohio, supposed to be of the age of the Chemung group of New York: *New York State Cab. Nat. History*, 17th *Ann. Rept.*, Appendix H, pp. 50–60.

——, and WHITFIELD, R. P., *1875*, Descriptions of Crinoidea from the Waverly Group: *Ohio Geol. Survey*, vol. 2, pt. 2, pp. 162–179, pls. 11–12.

LAUDON, L. R., and BEANE, B. H., *1937*, The crinoid fauna of the Hampton formation at Le Grand, Iowa: *Iowa Univ. Studies*, vol. 17, no. 6, new ser., no. 345.

MEEK, F. B., and WORTHEN, A. H., *1861*, Descriptions of new Paleozoic fossils from Illinois and Iowa: *Acad. Nat. Sci. Philadelphia, Proc.*, vol. 13, pp. 128–148.

——, *1865*, Descriptions of new Crinoidea, etc., from the Carboniferous rocks of Illinois and some of the adjoining States: *Acad. Nat. Sci. Philadelphia, Proc.*, vol. 17, pp. 155–166.

——, *1868*, Paleontology: *Illinois Geol. Survey*, vol. 3, pt. 2, pp. 289–565, pls. 1–20.

——, *1869*, Descriptions of new Carboniferous fossils from the Western States: *Acad. Nat. Sci. Philadelphia, Proc. for 1869*, pp. 137–172.

——, *1873*, Descriptions of invertebrates from Carboniferous system: *Illinois Geol. Survey*, vol. 5, pt. 2, pp. 321–619, +pp. i–v, pls. 1–32.

MILLER, S. A., *1889, North American geology and palaeontology for the use of amateurs, students and scientists*, pp. 1–664, Cincinnati, Ohio.

——, and GURLEY, W. F. E., *1890*, Description of some new genera and species of Echinodermata from the Coal Measures and Subcarboniferous rocks of Indiana, Missouri and Iowa: *Cincinnati Soc. Nat. History, Jour.*, vol. 13, pp. 3–25, pls. 1–4.

——, *1890a, Description of some new genera and species of Echinodermata from the Coal Measures and Subcarboniferous rocks of Indiana, Missouri and Iowa*, pp. 25 (part)-59, pls. 5–10. (Privately published. Continuation of paper of same title.)

SPRINGER, FRANK, *1926*, Unusual forms of fossil crinoids: *U. S. Nat. Mus., Proc.*, vol. 67, art. 9, no. 2581, pp. 1–137, pls. 1–26.

WACHSMUTH, CHARLES, and SPRINGER, FRANK, *1880*, Revision of the Paleocrinoidea, Part 1: *Acad. Nat. Sci. Philadelphia, Proc. for 1879*, pp. 226–376, pls. 15–17 [separates, pp. 1–153, pls. 1–3].

——, *1886*, Revision of the Paleocrinoidea, Part 3, Second Section: *Acad. Nat. Sci. Philadelphia, Proc. for 1886*, pp. 64–226. [Separates, pp. 139–302. One unnumbered page inserted after p. 302. One inserted page "Note to page 255." The latter appeared in two different forms. Index to pts. 1–3, pp. 303–334.]

——, *1889*, in Miller, S. A., *1889, North American geology and paleontology for the use of amateurs, students and scientists.* [Wachsmuth and Springer's species of 1890 appear here with illustrations, apparently constituting publication.]

——, *1890*, New species of crinoids and blastoids from the Kinderhook group of the Lower Carboniferous rocks at Le Grand, Iowa; and a new genus from the Niagara group of Western Tennessee: *Illinois Geol. Survey*, vol. 8, pt. 2, sect. 2, pp. 155–208.

WORTHEN, A. H., *1882*, Descriptions of fifty-four new species of crinoids from the Lower Carboniferous limestones and Coal Measures of Illinois and Iowa: *Illinois State Mus. Nat. History, Bull.* 1, Art. 1, pp. 3–38.

——, *1883*, Description of fossil invertebrates: *Illinois Geol. Survey*, vol. 7, pt. 2, sec. 2, pp. 265–338, pls. 27–30.

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A CRINOIDAL MARKING IN THE DUNDAS FORMATION AT TORONTO

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SOME layers in the Dundas formation (Upper Ordovician) are notoriously rich in a great variety of markings, trails and burrows, some of which are rather hard to explain satisfactorily. Among such markings, there is a fairly common one consisting of sets of parallel, sometimes slightly curving grooves. The spacing of such grooves varies but is of the order of 1 mm. between adjacent grooves. The grooves are commonly 20 mm. long, and 40 or 50 such grooves may make up a set.

No conclusive evidence of the cause of these markings was available until the junior author, during a geological field trip to the Don Valley Brick Yard quarry, found in the talus a specimen (fig. 1) containing similar markings under a crinoid column, evidently responsible for them. As can be seen from the illustration, the crinoid stem, apparently in a recumbent position, was moved back and forth over the soft bottom mud by wave or current action. The protruding edges of the segments of the stem drew a series of parallel markings on the mud. The variation in the coarseness of the similar markings mentioned above evidently depends on the size of the columnar segments, and their number on the length of the column in actual contact with the bottom.

Miss Madeleine Fritz[1] in 1925 described and illustrated a less obvious specimen with similar markings but refrained from offering a definite opinion as to their origin. She suggested, however, that they might have been made either by a crinoid swinging back and forth or by the appendages of trilobites. The finding of the new specimen definitely decides this problem in favor of the crinoid stem.

FIG. 1.—Crinoidal marking, ×2½.

[1] FRITZ, M. A., *1925*, The stratigraphy and palaeontology of Toronto and vicinity: *Ontario Dept. Mines*, 32d *Ann. Rept.*, p. 32, pl. 3, fig. 5.

JOURNAL OF PALEONTOLOGY, VOL. 15, NO. 1, P. 90, JANUARY, 1941

THE EOCENE DIBRANCHIATE CEPHALOPOD GENUS BELEMNOSELLA NAEF, 1922, = ADVENA PALMER, 1937, = ANEVDA PALMER, 1940

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K. V. W. PALMER (1937) described a highly interesting and exceedingly rare dibranchiate cephalopod from the middle Eocene Gosport sand of Alabama. This fossil, a single specimen, was described as *Advena floweri* Palmer, n. gen., n. sp., and was made the type of the genus *Advena* Palmer, 1937. According to Palmer the genus *Advena* includes only two species, the genotype species and *Advena americana* (Meyer and Aldrich), originally described as *Belemnosis americana* Meyer and Aldrich (1886). The latter species, too, is known from a single specimen only, which may have become lost by now.

Recently it has been pointed out that the generic name *Advena* is preoccupied by *Advena* Gude (1913). Therefore, Palmer (1940) proposed *Anevda* Palmer as a substitute for *Advena* Palmer, 1937, not Gude, 1913.

The two generic names, *Advena* Palmer, 1937, and its substitute *Anevda* Palmer, 1940, seem superfluous because an older and presumably valid generic name is available for this rare dibranchiate cephalopod genus. Naef (1922) proposed the generic name *Belemnosella* with *Belemnosis americana* Meyer and Aldrich as the monotype species. The species described by Palmer is then the second species of this rare genus and should go under the name *Belemnosella floweri* (Palmer).

The chief purpose of this paleontologic note is not so much to correct the generic names as to point out the importance of Naef's work for the understanding of the anatomy and structure of the Tertiary dibranchiate cephalopods, although some of the reconstructions of the shells made by Naef may be faulty. It is to be regretted that Tertiary dibranchiate cephalopods are so rare that it is rarely possible for a single investigator to obtain enough material for comparison of the various genera. Naef has presumably had greater opportunity to study and compare the different genera than anybody else.

REFERENCES

GUDE, G. K., *1913*, Definitions of further new genera of the Zonitidae: *Mal. Soc. London, Proc.*, vol. 10, p. 391.

MEYER, OTTO, and ALDRICH, T. H., *1886*, The Tertiary fauna of Newton and Wautubbee, Miss.: *Cincinnati Soc. Nat. History, Jour.*, vol. 8, no. 2, p. 47, pl. 2, figs. 26, 26a.

NAEF, ADOLF, *1922*, *Die fossilen Tintenfische*, pp. 48–50. Gustav Fischer, Jena. Naef lists accidentally *Belemnosella americana* Meyer and Aldrich as coming from "Missoury." It is, of course, from Mississippi.

PALMER, K. V. W., *1937*, The Claibornian Scaphopoda, Gastropoda and dibranchiate Cephalopoda of the southern United States: *Bull. Am. Paleontology*, vol. 7, no. 32, pp. 510–512, pl. 76, figs. 10–12, 15.

——, *1940*, *Anevda*, new name for *Advena* Palmer, 1937, not Gude, 1913: *Jour. Paleontology*, vol. 14, no. 3, p. 285.

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JOURNAL OF PALEONTOLOGY, VOL. 15, NO. 1, P. 91, JANUARY, 1941

DERBYA ARIZONENSIS, NEW NAME FOR D. REGULARIS McKEE

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MY ATTENTION has been called by Dr. Carl C. Branson to the fact that the name *Derbya regularis* was applied to a species from the Salt Range of India by William Waagen in 1882.[1] I was not aware of this prior use when I assigned the same name to another Permian species found in the Kaibab formation of Arizona.[2] As this latter species must be given a new name I propose to rename it *Derbya arizonensis*.

[1] WAAGEN, WILLIAM, *1882, Palaeontologia Indica*, ser. 13, vol. 1, pt. 4, fasc. 1, p. 594, pl. 53, figs. 1, 2, 4.

[2] McKEE, E. D., *1938, Carnegie Inst. Wash., Pub.* 492, pp. 226–227, pl. 44, figs. 3, 4.

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A METHOD OF PHOTOGRAPHING IMPRESSIONS OF FOSSILS

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THE FOLLOWING method has been used to make photographs of bryozoan impressions. It is believed that the method can be used to illustrate other fossils preserved as impressions that do not produce satisfactory casts.

The specimens selected for illustration were whitened with a thin film of ammonium chloride and photographed with a Leica camera equipped with a sliding focusing attachment. Care was taken that the specimens were evenly lighted, and that they lacked strong shadows. The resulting negatives were then printed on strips of positive film. The Leitz contact printing apparatus was used for this purpose. Printing the negatives on positive film reversed the image of the impressions so that the positive film appeared as if it had been taken directly from a normal specimen rather than from an impression. Finally, the positive film was enlarged on paper to make a figure of the desired size.

The illustrations produced in this manner are usually slightly flatter in appearance than the original specimen. This is due to the fact that the specimen must be very evenly lighted when it is photographed, because areas that have deep shadows do not show detail as high-lighted places on the final print.

This method was devised to illustrate delicate impressions by Bryozoa that were contained in a very soft clay matrix. Plasticine casts did not record enough surface detail to make enlarged photographs. Dental wax and liquid rubber removed surfaces of the impressions when the casts were pulled, and hardening the impressions in bakelite, Canada balsam and celluloid cement covered the finer details of the specimens. The optical illusion produced by lighting the specimen from the lower right rather than the upper left was also attempted but did not produce satisfactory results.

Minature camera equipment is not necessary in making this type of photograph. The negatives could be made with a camera using cut film or plates, and these could be contact printed on other film and the final prints made on paper.

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A MIOCENE ECHINOID COLONY FROM MARYLAND

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A NEW locality for the Miocene echinoid *Echinocardium orthonotum* (Conrad) was discovered in the Calvert Cliffs on the western shore of Chesapeake Bay during the summer and fall of 1938. The locality is in Calvert County, Md., approximately 2200 feet north of the stairway and artesian well at Scientists' Cliffs, which in turn is about 1½ miles north of Kenwood Beach (=Governor's Run), and about one mile south of the mouth of Parker Creek. The echinoids were found in a bed about 18 feet above mean high tide. They occur within a vertical range of three or four inches, and extend about 12 feet along the face of the cliff.

Early in the summer of 1938 loose echinoid plates were observed by the writer scattered over the surface near the base of the cliffs at this locality. Since it seemed likely that the plates had rolled down from some of the fossil beds above, search was made for the source of the fragments in the higher parts of the cliffs, but without success. The locality was revisited at intervals throughout the summer of 1938, and on each occasion more plates were found scattered over the surface. On August 5, three complete specimens were found. On November 5 and 6, 1938, the writer revisited the locality, and this time the source of the echinoids was found and uncovered for a distance of about 12 feet along the face of the cliff. The writer visited the locality again in May, 1939, and obtained additional specimens. In all she has obtained about 150 complete specimens from this locality.

During the summer of 1939 Mr. W. F. Foshag of the United States National Museum noticed the hole left by previous digging in the cliff, and rediscovered the echinoid bed. Later, Mr. James H. Benn and a group from the United States National Museum visited the locality and uncovered the bed for a distance of about 10 feet back into the cliffs. By covering the surface carefully with plaster of Paris and then undercutting the bed they were able to remove three slabs, each a yard or more square, which will eventually be prepared and put together for exhibit in the United States National Museum. A fourth slab was removed for exhibit at the Scientists' Cliffs colony. According to Mr. Benn, his work, also, indicated that the echinoids did not extend more than about 12 feet along the face of the cliff. There is no indication as to how far back into the cliffs the bed may extend, but from a practical working standpoint it was exhausted after the removal of the slabs for the United States National Museum.

The bed in which the echinoids were found consists chiefly of fine sand, but it also contains some dense, lumpy clay. The horizon is close to what should be the contact between the Calvert and Choptank formations of the Miocene, but since this writer has never been able to determine the contact of those two formations in the field, it is impossible to say whether the echinoids actually mark the contact. They occur about 18 feet below the bottom of Shattuck's (1904) zone 17 of the Choptank, although that zone is not well exposed at this exact locality.

The only forms found associated with the echinoids were barnacles, a few fragments of the sand dollar *Scutella aberti* Conrad, and a very few pelecypods, which were too soft and poorly preserved for determination.

Most of the echinoid specimens were slightly crushed, probably as the result of compaction by the weight of overlying sediments, though perfect examples were not rare. Many specimens otherwise perfect showed a crack along an anterior-posterior line through the center. The spines commonly remained attached, although they were so fine and fragile that it was impossible to collect and prepare the specimens so as to keep them articulated and unbroken. Most of the echinoids were found in the natural position in the bed, with the ventral side downwards. The majority were complete, and there were very few loose frag-

ments within the bed. Apparently there was not much breakage before the specimens were buried.

The echinoid was described by Conrad in 1843 from near Coggins' Point, James River, Virginia. Conrad named it *Spatangus orthonotus*, but did not figure it. It was reported by W. B. Clark (1904) from the Choptank formation at Jones Wharf, Maryland, and by Clark and Twitchell (1915) from the Yorktown formation of James River, Virginia. In Clark and Twitchell's Monograph on the Echinodermata the only stratigraphic occurrence mentioned is that of the Yorktown Miocene of Virginia.

The writer wishes to thank Mr. James H. Benn of the United States National Museum for reading the manuscript and offering suggestions.

REFERENCES

CLARK, W. B., *1904, Maryland Geol. Survey, Miocene*, pp. 430–432, pl. 119, figs. 1a–c.

——, and TWITCHELL, M. W., *1915, U. S. Geol. Survey, Mon.* 54, pp. 213, 214, pl. 97, figs.2a–c; pl. 98, figs. 1a–c, 2a–c.

SHATTUCK, *1904, Maryland Geol. Survey, Miocene*, p. lxxxi.

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JOURNAL OF PALEONTOLOGY, VOL. 15, NO. 1, PP. 94–96, 3 TEXT FIGS., JANUARY, 1941

FENESTRELLINA MULTISTRIATA, A NEW DEVONIAN BRYOZOAN FROM QUEBEC

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ABSTRACT—Through the recent efforts of the Quebec Bureau of Mines a considerable bryozoan fauna of Devonian age is being assembled. With the recognition of *Fenestrellina multistriata* described in this paper another particularly characteristic form is added to the growing list of species.

THE TWO examples of this species described below were collected by Dr. H. W. McGerrigle of the Quebec Bureau of Mines. The locality given is Cap des Rosiers Township, Range 1 South, lot 16 (?) on Roncelle road, about 1½ miles north of the shore of Gaspé Bay.

Before considering this new species I should like to take the opportunity of expressing my appreciation to Dr. McGerrigle and his colleagues for their continued interest in the collection of Gaspé bryozoa (Fritz, 1940) and, also, for the opportunity they have afforded me of studying and retaining their collections.

Order CRYPTOSTOMATA
Family FENESTRELLINIDAE Bassler
Genus FENESTRELLINA d'Orbigny

FENESTRELLINA MULTISTRIATA
Fritz, n. sp.
Figures 1–3

General features.—This species is known from two fragments of the zoarium, which appears to have been infundibuliform. Although the specimens represent only molds or impressions of the actual form, the detailed structure is very well preserved. The specimens lie side by side on a weathered limestone surface. One reveals the celluliferous side, the other the noncelluliferous. The larger fragment representing the celluliferous side is approximately 30 mm. wide by 20 mm. high; the smaller is 15 mm. by 10 mm. It may be that these two fragments are part of the same zoarium. In any case they represent the same species. The smaller fragment reveals a cast of a small part of the celluliferous side, which affords a comparison with the larger specimen.

Obverse.—Measured across the zoarium, three branches appear in the space of 2 mm. prior to a bifurcation. Bifurcation takes place at regular intervals. The fenestrules are distinctly elongate, being about 1 mm. long and 0.5 mm. wide. The dissepiments, which are stout and considerably shorter than the width of a branch, are noticeably broader at their point of junction with the branch. Three zooecia appear as a rule in the space of a fenstrule, with an additional one frequently occurring opposite a dissepiment. The zooecia are characterized by a distinct peristome, within which is a ring of granules numbering approximately from eight to 12. As the specimen is an impression, it shows the peristome only as a depression, and the granules as pits within the depression. There is evidence, also, of the opercular cover in the presence of a central pit larger than those constituting the peristomal rim. In the original specimen this structure must have been in the nature of a central opercular tubercle.

A well-marked carina is present on the branches. At regular intervals of 0.50 to 0.75 mm. a medium-sized node is developed on the carina.

The whole surface of the branch, including the dissepiments, is very prominently striated, the branches with vertical striations and the dissepiments with horizontal markings. The striations curve noticeably towards the dissepiments at the point of junction of the latter with the branches, thus producing a decidedly ornate appearance.

Reverse.—In contrast to the obverse side, the branches on the reverse are not carinated but well rounded, three appearing in 2 mm., measured transversely. A vertical

row of slightly more prominent nodes than those on the obverse side is developed medially along each branch. These nodes are spaced at a distance of approximately 1.5 mm. apart. The surface of the branches and dissepiments is striated similarly to the obverse side. These striations, however, appear even stronger and more continuous on the reverse; this fact is probably due to the absence of zooecia on the reverse side.

Remarks.—*F. multistriata* is easily distinguished from all other species previously recorded from Gaspé by its distinctly striated surface and by the ornate character of the peristomes and opercula. It is associated with the ostracode *Beyrichia acadica* Jones, which occurs in considerable abundance. The presence of this ostracode, which Clarke (1908) regards as characteristic of the Grande Grève limestone, strengthens the

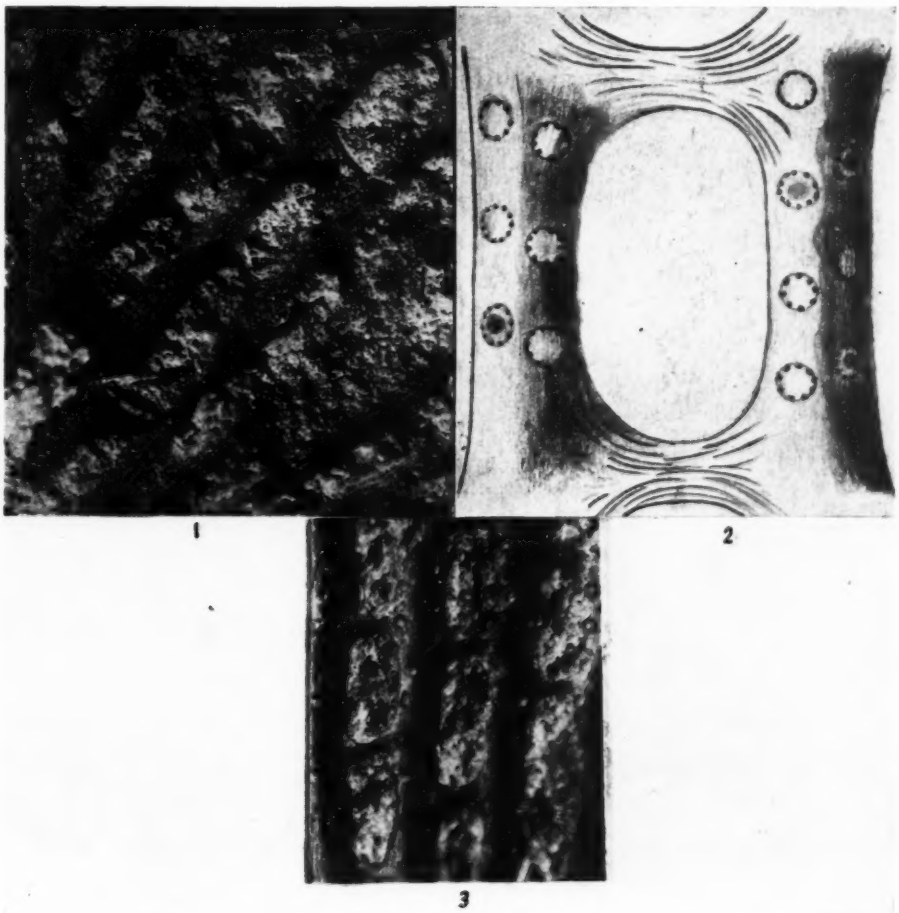

FIG. 1.—Photograph of reverse side ×16, showing well the character of the branching and the finely striated surface. Syntype 20973 Royal Ontario Mus. Palaeontology.
2.—Drawing of obverse side ×45 from one of the syntypes, showing the ornate character of the peristome, also, the opercula.
3.—Photograph of obverse side ×16, showing the character of the branches, dissepiments, and fenestrules as well as the position of the zooecia. Syntype 20973 Royal Ontario Mus. Palaeontology.

field evidence for the Grande Grève age of the strata represented at this horizon.

Syntypes.—20973, Royal Ontario Museum of Palaeontology, Toronto, Ontario.

Occurrence.—Grande Grève limestone, Cap de Rosiers Township, Gaspé County, Quebec.

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REFERENCES

CLARKE, J. M., *1908, New York State Mus., Mem.* 9, pt. 1, p. 43.

FRITZ, M. A., *1940,* Devonian Bryozoa from Fortin and Malbay Townships, Gaspé County, Quebec: *Royal Ontario Mus. Palaeontology, Contr.*, no. 4.

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